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WORKSHOP PROCEEDINGS

"Human Behavior and Performance as Essential Ingredients in Realistic Modeling of Combat – MORIMOC III"

Stephen A. Murtaugh, FS
Chair and Editor

27 – 29 March 1990
Center for Naval Analyses
Alexandria, Virginia

Proponents: Deputy Under Secretary of the Army
Operations Research
and
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DISCLAIMER

This Military Operations Research Society Workshop Proceedings faithfully summarizes the findings of a three day meeting of experts, users, and parties interested in the subject area. While it is not generally intended to be a comprehensive treatise on the subject, it does reflect the major concerns, insights, thoughts, and directions of the workshop leaders and participants at the time of the workshop.

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This proceedings provides the results of this MORS Workshop convened to.

1) Develop understanding of the extent to which human performance and behavior affect combat and inputs to military decisions and
2) Define approaches to including human performance factors in modeling and analysis of combat so as to account for the influence of humans in assessing the battlefield effectiveness of military forces.

Included are the reports of the five Working Groups, each assigned a specific problem in the following areas:

1) For which decision issues and at what levels are human performance factors "essential ingredients" to military decisions?
2) Develop understanding of human performance factors and data bases of such factors, including aggregation of such data and its validity.
3) How can historical combat data be used in modeling and analysis to provide effects of battle stressors on human performance and the impact on battle conduct?
4) Develop a plan by which behavioral sciences, human factors, and operations research efforts can be applied on efforts such as generation of needed human performance data and making such data usable in existing and future combat models.
5) Develop a conceptual approach to incorporating higher level behavioral factors in modeling/analysis to support decision issues. Include consideration of models driven by military objectives rather than attrition.

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CHAPTER I
INTRODUCTION

By: Stephen A. Murtaugh, FS, Workshop Chair

1. *WORKSHOP OBJECTIVES AND SCOPE*

The objectives of this workshop were to:

- develop understanding of the extent to which human performance and behavior affect combat and the inputs to military decisions, and
- define approaches to including human performance factors in modeling and analysis of combat so as to account for the influence of human behavior on the battlefield effectiveness of military forces.

While performance of individuals, crews, groups, and their leadership was a major interest, it was to be a factor only to the extent that it has meaningful impact on the results of combat.

A prominent guideline adhered to by the workshop was not to increase the complexity of combat models by the unwarranted inclusion of human factors detail, unless they have meaningful influence on the problem being analyzed. In cases where they have such influence, it is desired to include those human performance factors in combat modeling and analysis supporting military decision makers. The decision issues that would be supported by such models/analysis are:

- Force sizing
- Human resource planning
- Weapon procurement
- Battle planning
- Wartime operations
- Logistics planning
- National policy analysis

The workshop focused on five problems, each of which was identified and defined following review of the results of the predecessor MORIMOC II Mini–Symposium on this same topic that was held in February 1989. (see below and the Terms of Reference for MORIMOC III in Appendix A). Each of the problems was assigned to one of five working groups.

Working Group 1: Determine for which decision issues and at what level human performance factors are essential ingredients to combat analysis supporting military decisions.

Working Group 2: Develop understanding of human performance factors, associated hierarchical data bases, aggregation of such data, and viability of using non–combat data in combat models/analysis.

Working Group 3: Consider how historical combat data can be used to improve the quality of combat modeling and analysis, through such as validation of model results or influencing combat model design, including the aspects of human performance.

Working Group 4: Develop a plan by which behavioral experience, human factors, and operations research efforts can be steered and coordinated on such as generation of needed human performance data and making such data usable in existing computer models.

Working Group 5: Develop a conceptual approach to incorporating higher level behavioral factors in combat modeling/analyses to support decision issues. Include consideration of models driven by military objectives rather than attrition calculations and in which effects of group behavior may be included.

The first four problems all emphasized the development, understanding and application of human performance factors data in combat models and analysis methodologies used to support military decision makers. As such, they were to: (1) develop understanding and structure for including such parameters in existing combat models and (2) provide background for quantitative assessment of the magnitude of the effects of human performance and behavior (as a function of group size) relative to the effects already accounted for in many combat models (weapons effectiveness, fire rate, attrition, etc.).

Working Group 5 was to focus on developing a philosophy and a conceptual approach to a new type of combat model driven by achieve-

ment of military objectives. The focus in such a model is to be on higher level human performance factors (e.g., leadership, unit morale, cohesion in battle) especially as exhibited at battalion, company, and division level.

2. *MORIMOC CONTINUITY AND PARTICIPATION*

Not only was there direct philosophical continuity between MORIMOC II and III in that the problems tackled at the workshop were derived from the preceding mini-symposium's outputs, but there was also a strong physical continuity. Of those invited to attend MORIMOC III (participation was limited to 50), 36 of the people attending had been participants in MORIMOC II. In fact, 27 of this group were authors, discussants, or chairs from the preceding symposium. Also, the read-ahead packages the working group chairs selected for MORIMOC III made strong use of the MORIMOC II Proceedings—out of 33 papers available, 23 were chosen by the various chairs, 11 of which were selected by two or three chairs for workshop use.

There were two noteworthy and unique features of the MORIMOC II Minisymposium and the MORIMOC III Workshop. First was the diversity of technical specialists who attended and contributed to each program—not only operations analysts and military modelers, but also human factors specialists, psychologists, and behavioral scientists participated in each MORIMOC. Second was the participation from our NATO allies in each symposium—MORIMOC III was supported by nine participants coming from England, Canada, the Netherlands, and West Germany, plus the Director of the Operations Research Division at NATO's SHAPE Technical Center at the Hague. Both of these features were a first-time event for MORS on the scale that was accomplished in these meetings. These attendees added considerable enrichment and broadened points of view to the discussions and the results that were obtained.

3. *PERSPECTIVE OF THE WORKSHOP CHAIR*

At the Opening Session, the Workshop Chair briefed the participants on the scope of the problems to be addressed by the Working Groups and identified major concerns relative to the five assigned problems. A summary of that presentation is given here for background on and understanding of the scope and focus of the Workshop.

Figure I-1 portrays the basic process of interest—combat models and analysis being used to support decisions on the seven military decision issues. The focus of the workshop was on including human behavior and performance, along with military objectives (problem 5) as inputs to the models/analyses on a basis equivalent to the usual scenario, environment and weapons systems characteristics inputs. The first questions that come to mind are when does human behavior and performance affect combat and which decision issues are impacted? How

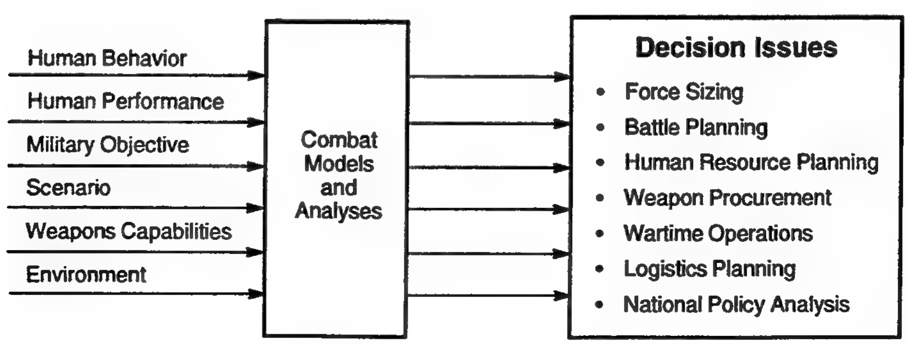

Figure I-1 THE BASIC PROCESS OF INTEREST TO MORIMOC III

much effect does which human behavior/performance factor have and in what circumstances?

Definitions of human behavior and human performance were offered for guidance–these definitions are:

> Human Behavior – response to stimuli in manners consistent or inconsistent with training, tactics, and doctrine; departure from established norms.
>
> Human Performance – ability to perform tasks and activities associated with technical operation of a system or the technical function of an executing element.

Stressors resulting from combat which can and do affect human behavior and performance were identified in MORIMOC II by Cherry and Alderman.*[1] These include:

Fatigue	Environmental:
Fear	• Thermal
Lack of Sleep	• Mechanical
Isolation	• Noise
Hunger, Thirst	• Visual
Surprise	• Toxic

However, measures are taken to counter the effects of such stressors on individuals and on groups. Such measures include realistic combat training, organization, discipline, and leadership. Combat experience also is a strong influence. Successful countering of these stressors helps ensure troop morale, cohesion in battle, and willingness to follow orders and press the attack.

An important aspect to be considered is which human performance factors are important in combat, and therefore in combat modeling and analysis? Are they dependent on such parameters as battle intensity or duration? Group size? Proximity to combat or enemy action (e.g., combat forces vs. combat support groups vs. combat service support groups)? Such insight is essential to knowing when to include human performance factors in combat modeling and analysis and which factors are to be included because they can affect the results. Knowing when and which to include of the range of human performance factors is a study in and of itself.

Such inputs can be ascertained from a combination of the following:

- Results of previous modeling and analysis that may be applicable
- Realistic combat training and exercises
- Battlefield commander combat experiences
- Historical combat data

Determining which human performance factors are applicable for a given situation is only one facet of the problem. A second is obtaining the human performance data needed and processing the data so it is useful in combat models. A suggested process is shown in Figure I–2. The needed human performance data is

* References are provided in Appendix B.

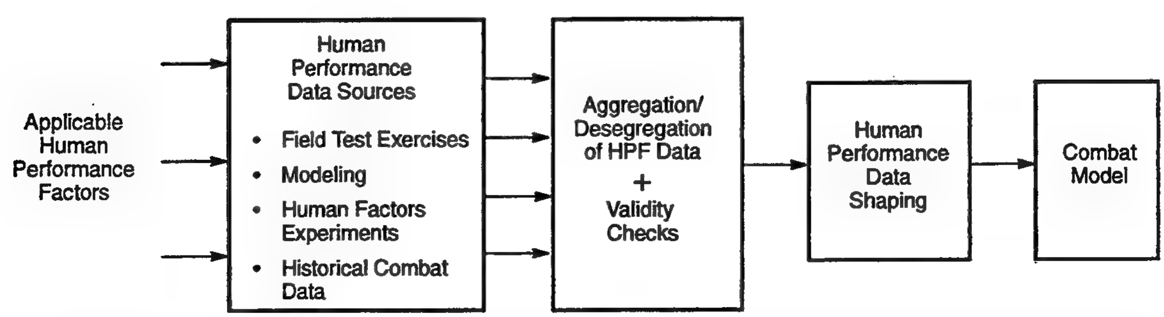

Figure I–2 SUGGESTED PROCESS FOR ACQUIRING AND PROCESSING HUMAN PERFORMANCE DATA FOR USE IN COMBAT MODELS

obtained from a variety of sources as suggested in the figure. Aggregation of the data is performed to account for group sizes different than that for which the data was obtained and to account for the effects of combat on human performance factors measured under non–combat conditions (Working Group 2).

The developed data needs one additional step of processing to make it amenable to use in computer models. This step develops statistical distributions and shaping functions from the data, and is an important aspect of the problem addressed by Working Group 4.

Several references have been made to the use of historical combat data. Historical records can be a rich source of information for such purposes as:

- supplementing measured/modeled human performance data
- providing effects of battle stressors
- validating measured or modeled data
- validating a combat model and its human performance inputs by comparing model outputs for a historical battle/engagement with the real world results.

Such factors fall in the general area of interest of Working Group 3.

The third step in this overall process is modification of existing combat models to accept the processed and shaped human performance data and employ it effectively within the model so as to generate the combat outcome as influenced by human behavior/performance.

This process is shown in Figure I–3. This topic is inherent in the problems assigned to Working Groups 3 and 4.

Working Group 5 was concerned with combat analysis and modeling at a higher level than is usually considered. The problem has two major aspects. First, this task was to consider the formulation of combat models which would provide a basis for estimating how to achieve stated military objectives—as opposed to the usual combat modeling approach of calculating relative attrition levels for opposing forces of various sizes. The objectives–driven model should provide meaningfull inputs and comparisons for use in a variety of decision issues (e.g., force sizing, battle planning, logistics planning), inputs that could hardly be derived from attrition–driven modeling of limited engagements.

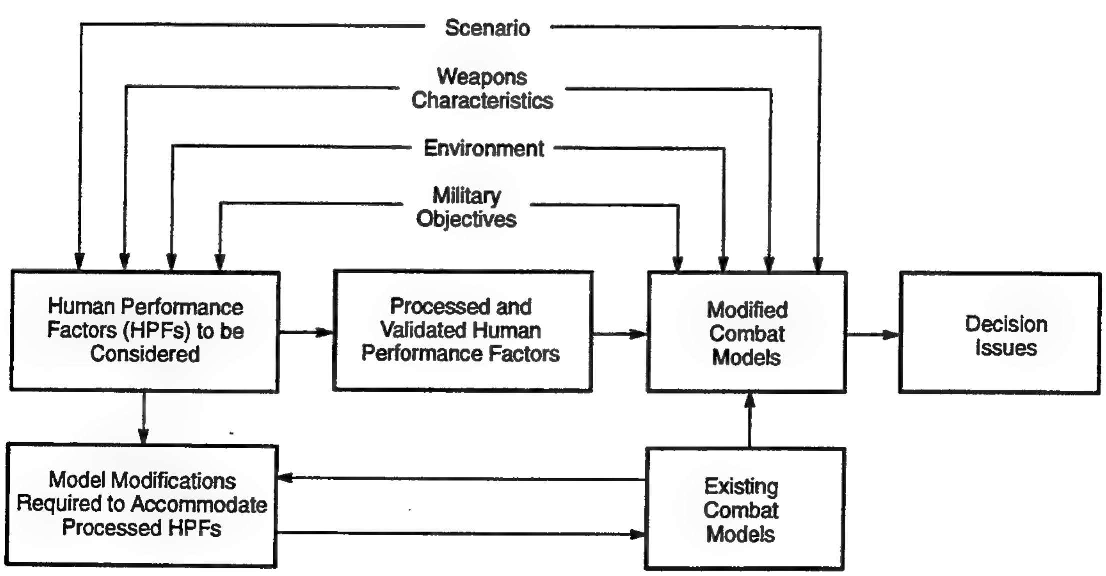

Figure I–3 OVERVIEW OF PROCESS FOR MODIFYING COMBAT MODELS TO ACCEPT HUMAN PEROFRMANCE DATA

The second aspect deals with the so–called higher level human behavioral factors—human performance at group levels (e.g., squad, company, battalion) as opposed to human factors at the individual or weapon crew level. In the larger groups, the influence of realistic training and conditioning (as from war game exercises), effectiveness of leadership, cohesion in combat, and previous combat experience are of interest. The concept for the new combat model should be formulated keeping in mind the need to include data (specific or parametric) representative of these higher–level behavioral factors in combat so that their influence is accounted for and can be measured. A suggested conceptual approach is offered in Figure I–4 in which the military objective (input) is compared with the computed military accomplishments (output) to provide the driver for modifying the battle strategy and/or tactics such as to overcome the opposing enemy force and achieve the assigned objective.

4. OBSERVATIONS

Now that this Workshop has occurred, and much time has elapsed for thinking about the deliberations and discussions that transpired, and the Proceedings of the Workshop have been written, several observations come to mind. These are presented here. They do not restate any of the conclusions or recommendations of the five working groups—those findings are recorded in the following five chapters of the Proceedings wherein each working group has documented what it felt it accomplished and cited the recommendations it developed.

1. At the time of the Workshop, it was recognized that the stated objectives and the scope of the problems assigned to the working groups were very ambitious, especially for a three day meeting. As a result, from this chair's point of view, the basic objectives of the workshop were not 100% achieved. On one hand, the second objective—dealing with approaches to incorporating human performance factors in combat modeling/analysis to support decision issues—was quite successfully attacked from several different points of view by several of the working groups. In fact, much innovation was shown. However, the first objective—of developing understanding of the extent to which human performance and behavior affect combat and decision issues—was a bigger task than could be achieved solely through the vehicle of a short workshop. This is not to say that the workshop provided no increase in understanding–quite the contrary! However, we learned that development of this understanding is a broad–rang-

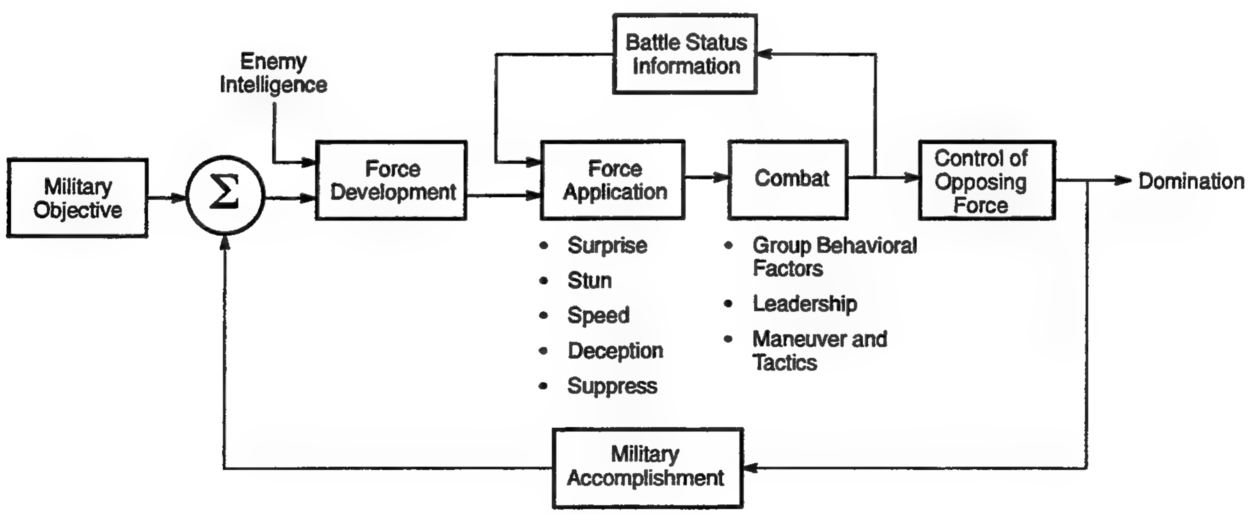

Figure I–4 CONCEPTUAL APPROACH TO COMBAT MODELING DRIVEN BY MILITARY OBJECTIVES AND INCLUDING HUMAN BEHAVIORAL FACTORS
(FROM MORIMOC II PAPER BY G. McMILLAN AND E. MARTIN)

ing task that will take a substantial effort. Some very useful work has been performed in this area and some of it was documented in the proceedings of MORIMOC II Mini–Symposium (see papers cited below). However, little scientific evidence exists that identifies which human factors—type and level—influence real combat and under which conditions they become important, and how such factors may vary with time during a battle and in ensuing battles.

- The strongest indicators are from experienced battlefield commanders who stress leadership, combat experience, and realistic training and conditioning as among the most important factors. (MORIMOC II – Whitehead).
- Certain combat modeling exercises have included a variety of human factors in the analysis and have identified the impact on battle results of the performance of individual soldiers, and weapons crews, and of battle commanders determination (see Sieman and Wolschlager; Anno and Dore, and Schecter).
- In other instances, limited training exercises have been valuable to isolate and identify causes of good or poor unit battle performance (see Cherry and Alderman).
- There is much to be learned from study and analyses of combat historic data with regard to the influence of behavioral factors on battle performance of combat units (see Dupuy, Dunnigan).

2. The workshop dealt with combat models that provide attrition results from engagement modeling and with what are termed military objectives–driven models. To the extent that human factors influence combat results, these factors should be included in both types of models.
3. Some very good and thorough analysis was done and some innovative outputs developed in the working groups. However, much remains to be done, not only in developing a thorough knowledge of the influence of human performance and behavioral factors on the outcome of groups engaged in combat, but also in the area of developing a coherent broad–based structure useful as a basis for organizing human performance data, selecting and prioritizing the data to be used for particular applications/analyses, and implementing modeling/analysis enhancements which will allow incorporation of human performance factors essential to and impacting a specific decision issue.

5. *ACKNOWLEDGEMENTS*

The members of each working group, along with the working group chairs, are identified in Appendix H. These are the folks who performed the work that was accomplished. In addition to this group, three senior analysts served as floaters among the working groups, offering their advice and experience to the deliberations as appropriate. These are Peter Cherry of Vector Research, Ron Speight of the NATO SHAPE Technical Center, and Clayton Thomas of USAF ACS Studies and Analysis. Dr. Phil DePoy, President of the Center for Naval Analysis, was very generous in allowing us the use of the CNA facilities for our workshop. Mary Pace, Vice–President for Administration of MORS, kindly provided the MORS society's welcome to the attendees at our opening session. It is appropriate that I also make note of the experienced administrative support of the MORS office staff—Dick Wiles, Natalie Addison, and Cynthia LaFreniere—without whose efforts there would not have been a workshop held. Finally, I wish to acknowledge the efforts of several people from the Calspan Advanced Technology Center in preparing this proceedings: Theresa Schwenk and Donna Weir for typing the text, and Ernest Hoefner and William Oesterle for graphic support. Thank you to all for your willing spirit, dedication, and effort.

CHAPTER II
REPORT OF WORKING GROUP 1: HUMAN PERFORMANCE FACTORS AS ESSENTIAL INGREDIENTS IN DECISION ISSUE MODELING AND ANALYSIS

Chair: Dr. Michael Strub, Chief U.S. Army Research Institute Field Unit, Fort Bliss, Texas

Working Group 1 addressed the following problem: For what decision issues and at what levels of combat models and analysis are human performance factors "essential ingredients" to military decisions? The problem statement was to be interpreted broadly so as to gain insight into such areas as: (1) when does human behavior affect combat and military decision issues?, (2) which human performance factors (hpf) create the effect and (3) what can be said about existing combat models accepting (or being modified to accept) near term hpf data bases and provide hpf–influenced output for support of decision issues?

The deliberations and findings of the working group reflected both the benefits and constraints associated with the varied backgrounds, fields, and affiliations of the group. In terms of specialty areas, there were four social scientists, four operations research analysts, and two modelers. In terms of affiliation, there were three NATO members (Canada, Germany, Netherlands), two U.S. Army Officers (Colonel, Major), three DOD civilians, and two industry personnel.

The working group chair requested each member to bring to the workshop responses to the various aspects of the problem statement. The original plan was to circulate these responses among the working group members and analyze them for consistency. However, analysis of the baseline replies proved futile. There was insufficient agreement to warrant continuing the analysis along these lines. Without some kind of definition of decision issues and human performance factors to work to, there was little chance of achieving group consensus.

The working group agreed that there was need to provide working definitions of human-performance factors, decision issues, and level of combat model. The group adopted an expedient course of action. For human performance factors, the working group elected to use a scheme developed by the SIMTECH 97 Working Group on Modeling "Soft Factors" reported in the December 1989 issue of Phalanx. There were five categories:

1. Cognitive Processes: factors affecting the decision making process such as creativity and doctrine, planning activities, and quality of decisions.
2. Human Factors: included in this category are such factors as fear, fatigue, suppression, leadership, morale, man–machine interfaces, individual differences, and level/quality of training.
3. Organizational Factors: this listing included structural patterns, continuity of operations, interoperability, cultural differences, and the quality of command and control.
4. Environmental Factors: this category includes environmental pressures on the command and control system such as deception, surprise, escalation, pace of battle, and the impact of combat experience.
5. Soft Effects: includes such issues as delay, disruption, cohesion, reconstitution, synchronization, effectiveness, and efficiency.

A listing of decision issues was adopted, based on the categorization scheme for military models identified and defined in the MORS Monograph "Military Modeling" (pages 4 and 23). Decision issues were divided into seven areas: force sizing, battle planning, human resource planning, weapons procurement, wartime operations, logistics planning, and national policy analysis. The working group accepted the definition of these "issues" as presented in the reference.

The third problem statement variable was the level of the combat model. The working group members settled on the following levels: item, battalion, corps, and theater or above.

The resulting operational definitions of human performance factors, decision issues, and combat model level provided a basis for further

analysis. The working group generated a 4x7 matrix showing the four levels of combat models and seven decision issues. Each working group member indicated, based on his knowledge, how many of the five human performance factors were applicable for each combination of combat model level and decision issue. Thus, each cell could have anywhere from 0 to 5 entries. There were no entries for the National Policy Decision Issue due to lack of knowledge in the category.

Those cells with the greatest number of entries and those cells in which a single factor was included by all or all but one member were highlighted. Based on this ranking scheme, the results are shown in Table II–1.

Table II–1
RESULTS OF WORKING GROUP SURVEY ON HUMAN PERFORMANCE FACTORS APPLICABILITY TO DECISION ISSUES AND LEVEL

Decision Issue	Level	Human Performance Factor
Force Sizing	Corps	All
Battle Planning	Battalion/Corps	All
Human Resource Plan	Item, Battalion, Corps	All
Weapons Procurement	Item	Human Factors
Wartime Operations	Battalion, Corps	All
Logistics Planning	Item	Human Factors
National Policy	–	–

Recall that the working group problem was to determine "In what decision issues and at what levels are human performance factors essential ingredients to military decisions?" The information in the above listing directly feeds the problem statement. The working group determined that all human performance factors are essential in four of the six decision issues considered. There is clear evidence of interactions among all three variables (decision issue, level, hpf). For the decision issue of Human Resource Planning, hpf were determined to be essential at all levels except theater and above while for Force Sizing, they are important only at the Corps level. For Battle Planning and Wartime Operations, battalion and corps are the levels at which human performance factors were considered essential by the working group. For Weapons Procurement and Logistics, human factors were the most important of the hpf and were deemed to be important only at the item level.

While these results covered the main problem statement, they did not address the extent to which existing combat models could accept or be modified to accept near term hpf data bases and provide hpf–influenced output for support of decision issues. The working group agreed that the 4x7 matrix could serve as a framework for listing which combat models dealt with each decision issue at each level prior to examining its capability of accepting hpf data. The collective knowledge of the working group revealed the following models that would be appropriate to supporting each decision issue at various levels–these are listed in Table II–2.

There was limited knowledge within the group concerning the awareness of the extent to which existing combat models accepted or could be modified to accept hpf. Four such models were identified, although it is recognized that there are many others which can and have accepted hpf data. These models and the hpf factors they accept are as follows:

JANUS	– Radiation decrement
VIC	– Radiation decrement
FORCEM	– MOPP gear Radiation sickness
KORA	– Personnel strength (as affected by fatigue and stress) Fire rate Probability of kill

Valid results would be very useful in pinpointing where limited resources might be invested toward integrating human performance factors into combat models. One might be tempted to conclude that, based on the survey and the awareness of those models with some capability for accepting hpf, first priority should be given to VIC, KORA, and JANUS. However, these findings must be viewed with caution for a number of reasons. First, the survey and matrix design evolved from expediency. It was not developed in advance for use in the session. Second, there was insufficient time for in–depth discussion concerning the scope and meaning of

Table II–2
APPLICABILITY OF COMBAT MODELS TO EACH DECISION ISSUE AND LEVEL

Decision Issue	Level			
	Item	Battalion	Corps	Theater & Above
Force Sizing		JANUS	VIC CORBAN KORA	FORCEM CEM JTLS
Battle Planning		ARTBASS JANUS	KORA JANUS	JTLS VECTOR2
Human Resource Planning	SIMNET COFT	ARTBASS JANUS	JESS KORA JANUS	JTLS RSAS
Weapons Procurement		CASTFOREM JANUS	VIC CORBAN VECTOR3	CEM FORCEM
Wartime Operations				
Logistics Planning			KORA	CEM FORCEM
National Policy Analysis				RSAS

(Models are defined in List of Acronyms, Appendix C).

each of the seven decision issues and the five human performance factor categories used. An indication of the resulting lack of clarity surfaced when the question arose (after the working group had completed its survey) as to which decision issue embraced the training models. While it was agreed that the training models would fit best under the Human Resource planning decision issue, many members indicated that they failed to give adequate attention to training models in their ratings. It was agreed to re–rate the Human Resource Planning decision issue to include training models. The revised ratings resulted in three levels within Human Resource Planning (shown in Table II–1) being among the "consensus" cells. Also, it is not clear that there was common agreement concerning the hpf classification. While the SIMTECH 97 reference identified and defined the hpf categories, each member's own understanding of what constituted a category may well have interfered with relying on definitions from the reference.

Thus, the results of the survey analysis must be considered tentative. However, the approach developed might serve as a basis for an improved follow–on survey.

The working group generated the following suggestions:

1. Develop a more comprehensive hpf list and define a set of decision issues for use in a survey of a larger group of knowledgeable people (e.g., attendance of a future MORS symposium). The idea would be to follow a similar approach as that used by the working group. With improved definitions of hpf and decision issues and a larger sample size, the results would be more persuasive in terms of guiding resource allocation.
2. Develop better methods for improving communication between the human factors and the combat modeling communities. One area for dialogue might deal with common output forms used by human factors scientists such as curves of decay, growth, and stress variation with time in which curves the variance tends to increase as the mean performance decreases.
3. Establish a small, interdisciplinary team to develop a model for a specific problem that includes hpf.

CHAPTER III
REPORT OF WORKING GROUP 2:
HUMAN PERFORMANCE FACTORS AND THEIR AGGREGATION

Chair: Dr. Valerie Gawron, Calspan Corporation, Buffalo, NY

The initial statement of objectives for Working Group 2 was as follows:

Develop understanding on the broad issue of human performance factors and human performance factors data bases, considering such standpoints as:

- How to aggregate/desegregate data validly? When needed? What are the limits?
- As level of aggregation increases, which factors matter less? More?
- What are the needs for interpretation of unit or group behavior for use in combat models/analysis?

Aggregation of data is dependent on the type and use of such data. To address types of data, the working group first developed a hierarchy of human performance factors. Data in the same branch of the hierarchy could be aggregated by summing the effects. Data in different branches of the hierarchy have to be evaluated for interactive effects before any aggregations can be attempted. Because the human performance factors need to be identified prior to aggregation, the group revised the objectives accordingly and then worked first on the needed hierarchy. Accordingly, methodology for identifying and aggregating human factors for use in such as combat analysis and modeling became the focus of the group's activities.

The revised objectives of Working Group 2 are listed below:

- Develop a hierarchy of human factors important to combat analysis/ modeling.
- Develop a hierarchy of human performance measures.
- Identify data sources that contain the human performance measures as a function of human factors.
- Develop a method to aggregate human factors data across levels of detail.
- Map human factors to levels of detail.

1. HIERARCHY OF HUMAN FACTORS

As part of the work–ahead package, all members of Working Group 2 received the hierarchy of human factors presented in Gawron, Travale, and Neal (1989).*s As part of this review, members were asked to identify human factors which should be added to the hierarchy to reflect the needs of combat analysts and modelers. Some of these additional human factors come from the literature (e.g., physical strength from Visco, 1989), while others came from the experience of the group (e.g., organization). The resulting hierarchy had four major branches (environment, operator, task, and organization) and is presented in complete form in Appendix D. Note that:

1. all these factors seem to contribute to defining the context in which soldiers perform and, thus, can affect how they perform;
2. the groups of factors are all somewhat orthogonal to one another; therefore, it seems more straightforward to keep them separate than to interweave them;
3. the terms are rather ambiguous and sometimes controversial, but have been copied from reference materials where possible, instead of creating our own in an attempt to minimize confusion;

*See references listed at end of this chapter.

4. definitions of the terms can be found in the designated references; and
5. some of the factors have been defined at more levels of indenture than are shown.

2. HIERARCHY OF HUMAN PERFORMANCE MEASURES

The hierarchy of human performance measures developed by Meister (1986) was used as the starting point for developing a hierarchy of human performance measures to be considered in combat analysis and modeling. Meister's hierarchy included items 1 through 7 of Table III–1. Items 8 and 9 were added in deference to analyzing the impact of human performance on combat effectiveness. The complete hierarchy of human performance measures is presented in Appendix E.

Table III–1
HIERARCHY OF HUMAN PERFORMANCE MEASURES

1.	Time
2.	Accuracy
3.	Amount Achieved
4.	Frequency of Occurrence
5.	Physiological/Behavioral State
6.	Behavior Categorization by Observers
7.	Consumption
8.	Workload
9.	Probability

3. DATA SOURCES

Expertise resident within the working group was able to identify data sources for each of the human factors contained in the hierarchy described in Section 1. Following the working group meeting, working group members obtained complete references and annotated these as to the type of data contained in each (see the annotated bibliography provided at the end of this chapter) for each data source. To aid the analyst or modeler, the data sources are included as a column in Appendix D–1. For ease of access, we have also included agencies wherein relevant expertise and data may be found. Finally, we developed Table III–2 as a quick reference of the characteristics of the human senses.

4. AGGREGATION

Aggregation of human factors in combat analysis and modeling has traditionally been treated as addressing differences in the levels of detail of the entities being modeled. Cherry and Alderman (1989), for example, identified three levels of detail: global, mission, and task. Similarly, others have identified aggregation as the "degree of abstraction in the representation of such elements as: process...; situation...; force representation...; human factors... ". (Gilbert, Downes–Martin, and Payne, 1989).

Our working group built on this approach in developing aggregation procedures. We began by distinguishing aggregation, disaggregation, and hierarchy. Our definitions are given below:

Aggregation: *process* of moving to lower levels of detail or resolution.

Disaggregation *process* of moving to higher levels of detail or resolution to identify determinate parameters.

Hierarchy *composite structure* of appropriate levels of progressive detail.

We then defined four types of aggregation as presented in Figure III–1. The procedure for vertically aggregating entities (e.g., going from task to individual) has both a top–down and bottom–up component. The top–down procedure includes identifying the level of detail of critical entities and then identifying specific entities which need to be included in the analysis or model of the critical entities.

Two procedures were developed to identify critical entities. First, for high levels of detail, the mission conditions and published doctrine and tactics are reviewed by subject matter experts and a Delphi method used to determine the entities which may drive the results of the mission as well as the linkages among these entities. Second, for low levels of

Table III–2
CHARACTERISTICS OF THE SENSES

Parameter	Vision	Audition	Touch	Taste and Smell	Vestibular
Sufficient stimulus	Light–radiated electromagnetic energy in the visible spectrum	Sound–vibratory energy, usually airborne	Tissue displacement by physical means	Particles of matter in solution (liquid or aerosol)	Accelerative forces
Spectral range	Wavelengths from 400 to 700 μ (violet to red)	20 cps to 20,000 cps	> 0 to < 400 pulses per second	Taste–salt, sweet, sour, bitter. Smell–fragrant, acid, burnt, and caprylic	Linear and rotational accelerations.
Spectral resolution	120 to 160 steps in wavelength (hue) varying from 1 to 20 μ	~3 cps (20 to 1000 cps) 0.3 percent (above 1000 cps)	Δpps – ≅0.10 pps	–	–
Dynamic Range	~90 dB (useful range for rods = 0.00001 mL to 0.004 mL; cones = 0.004 mL to 10,000 mL	~ 140 dB 0 dB = 0.0002 dyne/cm²	~ 30 dB 0.01 mm to 10 mm	Taste ≅ 50 dB 3 x 10⁸ to 3% concentration quinine sulfate. Smell = 100 dB	Absolute threshold ≅ 0.2°/sec/sec
Amplitude resolution $\frac{\Delta I}{I}$	contrast = $\frac{\Delta I}{I}$ = 0.015	0.5 dB (1000 cps at 20 dB or above)	~ 0.15	Taste ≅ 0.20 Smell: 0.10 to 50	~ 0.10 change in acceleration
Acuity	1° of visual angle	Temporal acuity (clicks) ≅ 0.001 sec	Two–point acuity = 0.01 mm (tongue) to 50 mm (back)	–	–
Response rate for successive stimuli	~ 0.1 sec	~ 0.01 sec (tone bursts)	Touches sensed as discreet to 20/sec.	Taste ~ 30 sec Smell ~20 sec to 60 sec	~ 1 to 2 sec nystagmus may persist to 2 min. after rapid changes in rotation
Reaction time for simple muscular movement	~ 0.22 sec	~ 0.19 sec	~ 0.15 sec (for finger motion, if finger is the one stimulated)	–	–
Best operating range	500 to 600 μ (green–yellow) 10 to 200 footcandles	300 to 6,000 cps 40 to 80 dB	–	Taste: 0.1 to 10% concentration	~ 1G acceleration directed head to foot.
Indications for use	1. Spatial orientation required. 2. Spatial scanning or search required. 3. Simultaneous comparisons required. 4. Multidimensional material presented. 5. High ambient noise levels (Javitz, 1961)	1. Warning or emergency signals. 2. Interruption of attention required. 3. Small temporal relations important. 4. Poor ambient lighting. 5. High vibration or G forces present. (Javitz, 1961)	1. Conditions unfavorable for both vision and audition. 2. Visual and auditory senses (Javitz, 1961)	1. Parameter to be sensed has characteristic smell or taste (i.e., burning insulation).	1. Gross sensing of acceleration information
References	Baker and Grether (1954) Chapanis, Garner, and Morgan (1949) Woodson (1954) Wulfeck, et al. (1958)	Licklider (1951) Licklider and Miller (1951) Rosenblith and Stevens (1953) Stevens and Davis (1938)	von Bekesy (1959) Jenkins (1951)	Pfaffman (1951)	Wendt (1956)

(from Wulfeck, et al. (1958))

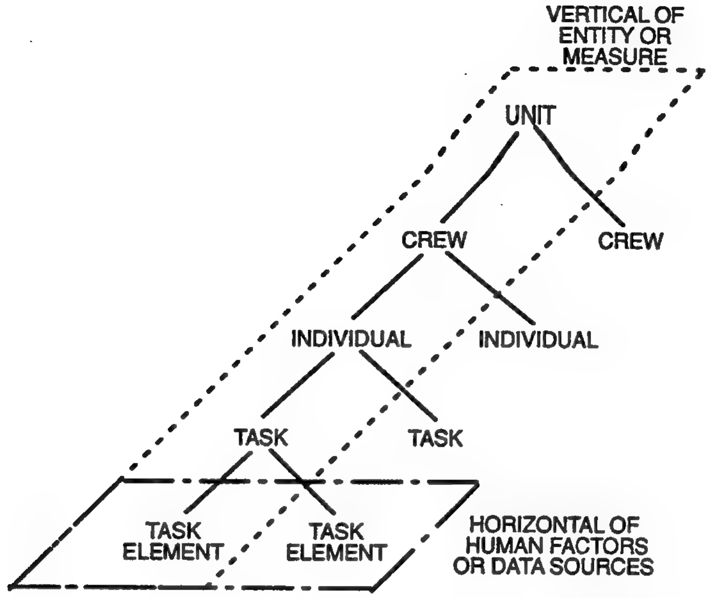

Figure III–1 FOUR TYPES OF AGGREGATION

detail, a response surface technique is used to identify mission–critical factors and these then are incorporated into a single mathematical equation using regression techniques. For example, the dimensions of the surface could be performance (e.g., reaction time) associated with factor 1 (e.g., number of alternatives) and with factor 2 (e.g., signal rate) and the equation would be:

RT = 0.831 + 0.092 (number of alternatives) + 0.001 (signal rate)

Specific entities to be analyzed or modeled are identified in a two–step procedure. First, a top–down approach is used to identify the highest level of detail at which human factors significantly impact combat outcome. Second, the entities affected by these human factors at this level are then identified using sensitivity–analysis techniques.

The bottom–up component also has two steps: 1) identify the human factors appropriate to the level of detail being considered using the human factors hierarchy and 2) review the available human factors data as identified in Appendix D to estimate the magnitude of their effect on the mission being analyzed and/or modeled.

Vertical aggregation of measures requires: first, defining the measure (e.g., time, distance, probability, errors) most relevant to the critical entities being analyzed or modeled and second, using a hierarchy of models to work between levels of detail. An example of such a hierarchy, developed for the Air Force's Cockpit Automation Technology (CAT) program, is presented in Figure III–2. It shows four levels of detail for the modeling–from human factors up to force–on–force. Timeline data of the battle field environment is developed separately in a force–on–force model and its outputs are used in the level 1 human factors modeling. Examples of resultant performance measure hierarchies, in pyramid form, are given in Figure III–3 for the three primary measures: mission effectiveness, aircrew compatibility, and cost, which illustrates their independence of each other.

Horizontal aggregation of human factors effects was categorized into five cases. The definitions of and procedures for handling each case are given in Figure III–4. The cases were defined based on the existence of combined human factors data, the range over

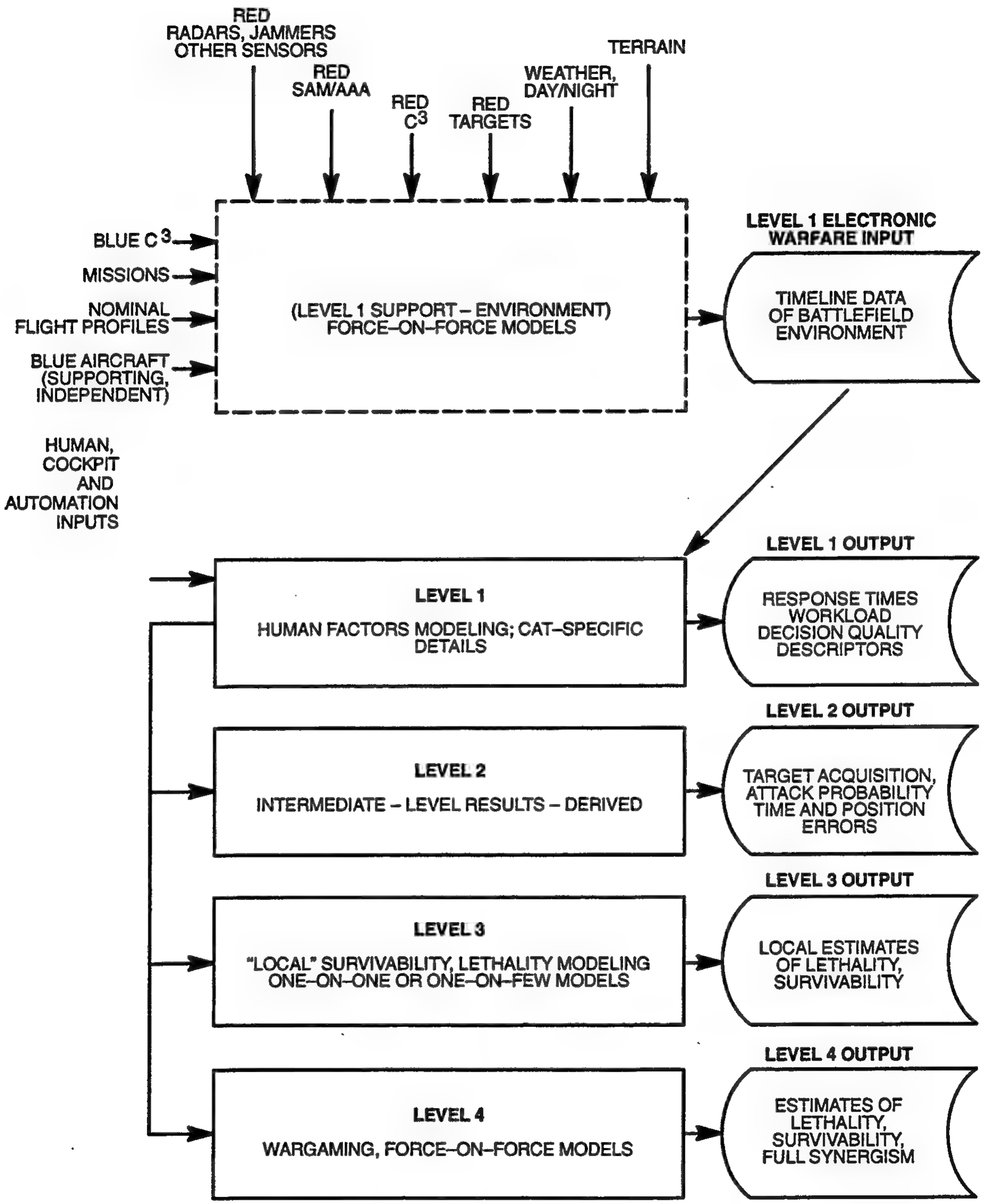

Figure III–2 STRUCTURAL CONCEPT FOR COCKPIT AUTOMATION TECHNOLOGY EVALUATION TOOLS

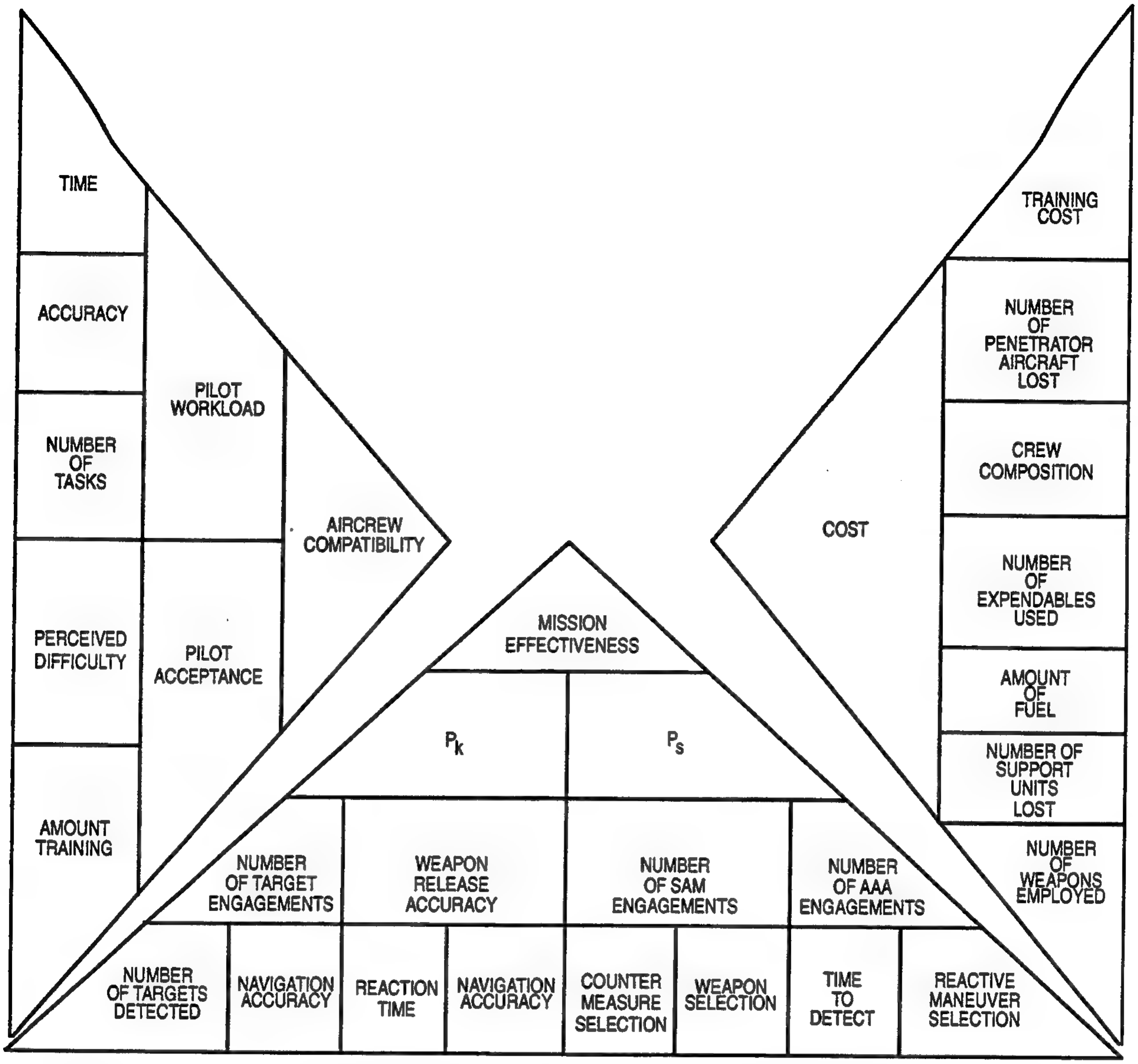

Figure III–3 EXAMPLE OF PERFORMANCE MEASURE HEIRARCHIES FOR MISSION EFFECTIVINESS, AIRCREW COMPATIBILITY, AND COST MEASURES

which the data are needed, and the time and resources available.

A method for horizontal aggregation of data across various data sources was developed by Lovesey (1989) using empirical data. The resulting performance weighting factors between various types of data sources are given in Figure III–5. These factors are multipliers for converting performance data obtained from one data source to those of another data source. The factors reflect the decrease in performance between highly simplified laboratory studies and actual combat conditions. A conceptual perspective of the various factors–machine and human–contributing to degradation of operational performance/effectiveness, from Lovesey's report, is, presented as Figure III–6. Figure III–7 gives some ranges of values for degradation factors such as those illustrated in Figure III–5. For

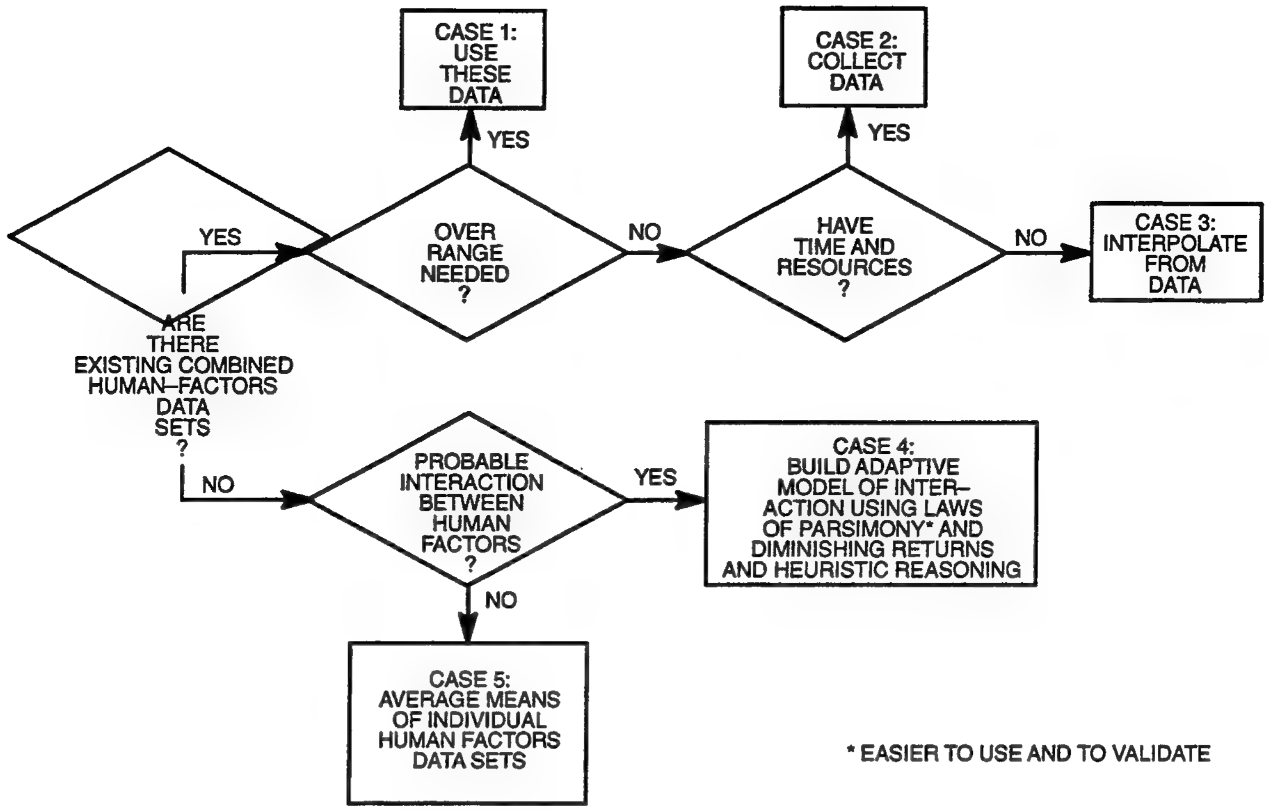

Figure III–4 HORIZONTAL AGGREGATION OF HUMAN–FACTORS EFFECTS

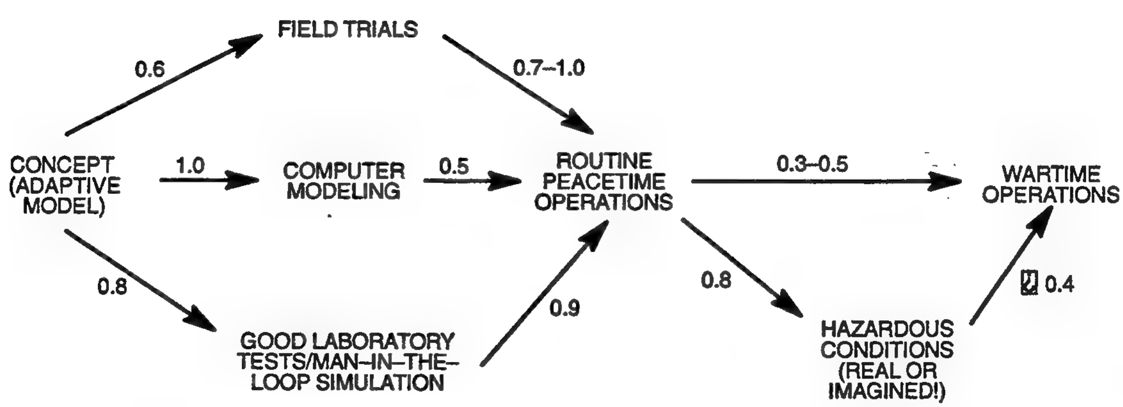

Figure III–5 A METHOD OF HORIZONTAL AGGREGATION ACROSS DATA SOURCES DEVELOPED BY E. J. LOVESEY

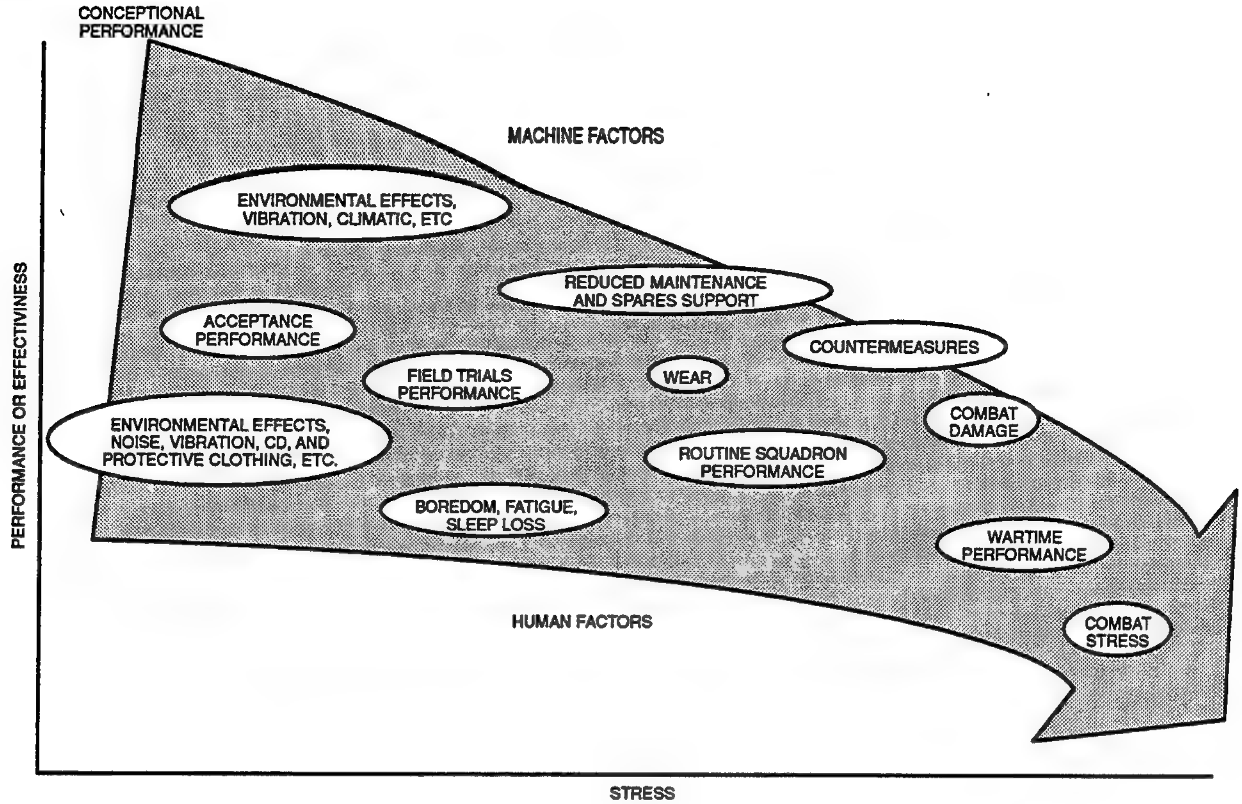

Figure III–6 SOME FACTORS CAUSING OPERATIONAL DEGRADATION

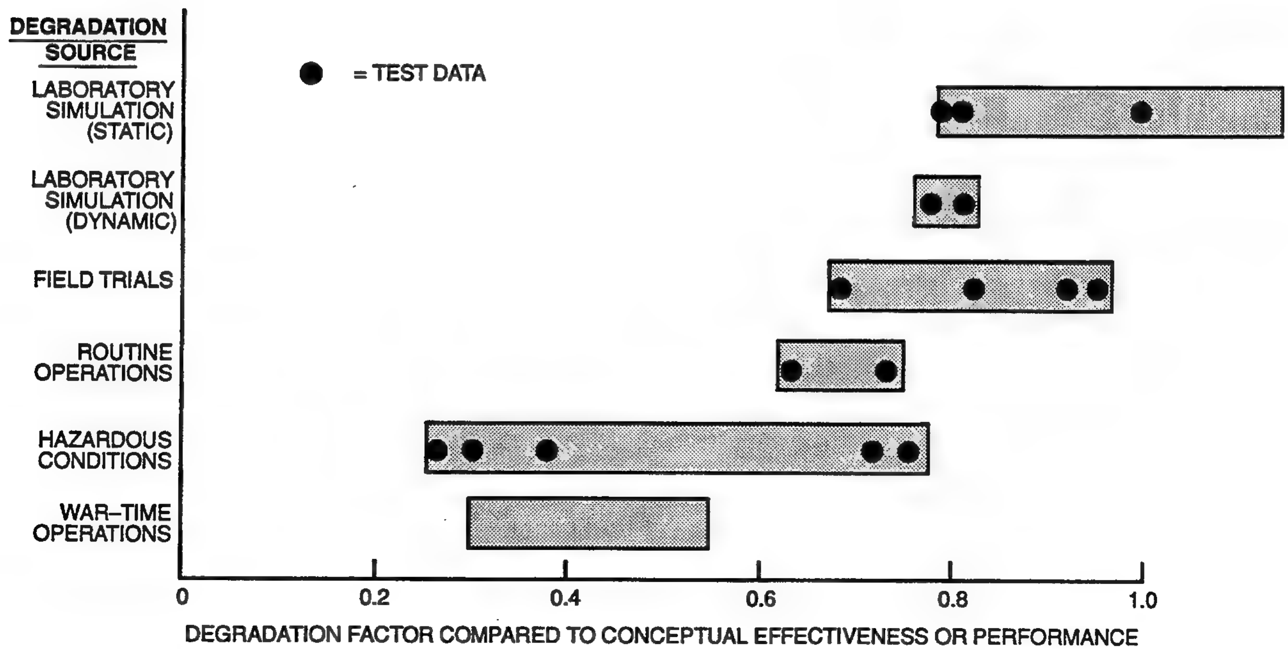

Figure III–7 FACTORS FOR QUANTIFYING THE DEGRADED CONCEPTUAL PERFORMANCE OF A SYSTEM PROGESSING THROUGH DEVELOPMENT AND OPERATIONAL USAGE

example, the effectiveness of a system during routine operations might range from 0.6 to 0.75 of its conceptual system performance, aid in war–time operations may degrade to as little as 0.3 to 0.5 of its conceptual performance.

4.1 Aggregation Algorithm Caveats

To further guide the combat analyst/modeler, we developed the following list of caveats for using the aggregation algorithms.

1) know the purpose of actions being modeled,
2) consider the feedback of outcome to action,
3) compute individual data points rather than interpolate from a surface, where possible,
4) do not use an additive model of degradation factors since you may get unreasonable results, so build a model instead,
5) seek human factors (HF) expertise to build models; note an Adelphi approach is best,
6) document your assumptions,
7) define upper and lower limits for dependent variables, e.g., RT (Reaction Time) cannot be less than 50 msec,
8) be reasonable when extrapolating,
9) beware of the potential for chaos, e.g., needing a critical mass or combining fault tree probabilities,
10) know what weighting factors are in your model,
11) don't confuse the model with what you're modeling,
12) check if your model includes criticality implicitly,
13) don't lose sight of the problem for the hierarchy, and
14) note that some things should be considered concurrently.

5. MAP OF HUMAN FACTORS TO LEVELS OF AGGREGATION

Hoffman (1989) raised the question "What is an appropriate level of significance for measuring these [human factor] effects?" Working Group 2 attempted to map items from the human factor hierarchy to the levels of detail identified during aggregation (see Figure III–8). We concluded that human factors (of some type) are needed at every level of detail.

	HUMAN FACTOR			
LEVEL OF DETAIL	ENVIRONMENT	OPERATOR	TASK	ORGANIZATION
UNIT	●	●	●	●
CREW	●	●	●	●
INDIVIDUAL	●	●	●	●
TASK	●	●	●	●
TASK ELEMENT	●	●	●	●

Figure III–8 MAP OF HUMAN FACTOR TO LEVELS OF DETAIL

6. *HUMAN FACTORS BASED PROCEDURE FOR COMBAT ANALYSIS AND MODELING*

The human factors based procedure for combat analysis and modeling developed by Working Group 2 is presented in Table III–3.

Table III–3
HUMAN FACTORS BASED PROCEDURES FOR COMBAT ANALYSIS AND MODELING

1.	Identify human factors relevant to current problem (use HF hierarchy)
2.	Review data available — if no data, create model (e.g., detail level model of specific human factors) — review available data for significance and quality
3.	Refine set of human factors to identify those with greatest impact on combat effectiveness
4.	Aggregate as needed
5.	Build model to support decision issue of interest

We tested and refined this procedure by applying it to two of the seven decision issues presented by the Workshop Chair in his opening presentation to the attendees, specifically, weapon procurement and wartime operations. These issues were selected because of their diversity, their extreme ranges of human factors impact, and available data.

7. *EXAMPLES*

To test both the procedure listed in Table III–3 and the hierarchies presented in Appendices D and E, we set up mission analyses to address two decision issues: weapon procurement (see Example 1) and wartime operations (see Example 2).

Example 1: Weapon Procurement What is the Effect of Air Conditioning on Combat Effectiveness of Radar Operators in a Van?

Step 1 IDENTIFY RELEVANT HUMAN FACTORS:

1.2 Confinement
1.3 Contaminants
1.8 Noise
1.2.12 Temperature
1.15 Vibration
2.1.3 Fatigability
2.2.1 Attention Span
2.2.6 Work Schedule
(2.2.8) Abilities
(2.3.1) Senses
3.1.1 Controls
3.2.1 Displays
3.4.1 Auditory Stimulus
3.5 Task
4.13 Climate/Morale

Step 2 REVIEW DATA

Various sets of data were found to be partially useful–three sets (identified here as a, b, and c) while incomplete singly, would provide data for all human factors of impact when combined (see table for Step 4).

Step 3 REFINE SET OF HUMAN FACTORS TO IDENTIFY THOSE WITH GREATEST IMPACT ON COMBAT EFFECTIVENESS

1.2 Confinement is not an issue—based on MIL–STD–1472D

1.3 Contaminants are not an issue—assume benign environment

*1.8 Noise must be considered if >80 dB and/or in 20 Hz–20 kHz Range

1.2.12 Temperature is important >20°C.

*1.15 Vibration if between 4–40 Hz

*2.1.3 Endurance is important since it interacts with temperature but will be

treated as an intervening variable.

*2.2.1 Attention span ability is important since it interacts with temperature but will be treated as an intervening variable.

*2.2.6 Work schedule is important since it interacts with temperature.

2.2.8 Abilities eliminated since groups are equivalent (standard ASVAT).

2.3.1 Senses affect aggregate since groups are equivalent (standard military).

*3.1.1 Controls important since type of control interacts with temperature on performance, (e.g., trackball).

*3.2.1 Display important since display type interacts with vibration.

*3.4.1.1 Auditory stimulus is a constant since interacts with noise

*3.5 Task important since it interacts with temperature; different task types differentially affected.

*4.13 Morale/group climate is important since air conditioning enhances short-term performance.

Step 4 AGGREGATE HUMAN FACTORS EFFECTS

Data Sets			Human Factor
a	b	a	Noise
c	b	a	Temperature
		a	Vibration
	b		Attention Span
	b		Work/Rest Schedule
	b		Endurance
		a	Control Type
		a	Display Type
		a	Auditory Stimulus
	b	a	Task Type
c			Morale

Step 5 The next step would be to develop and use the next higher level model so as to assess the effects of the human factors on the system effectiveness.

Example 2: Wartime Operations What Would Be the Outcome of a Falkland Islands–type Conflict?

Step 1 IDENTIFY RELEVANT HF

- 1.4 Day/Night Cycle
- (1.6) Isolation
  - 1.9.2 Sand
  - (1.10.1) Pressure
  - 1.2.12 Temperature
- *1.3 Terrain
- *1.2 Wind
  - *1.2.16 Enemy Situation
  - *1.2.17 Precipitation
  - *1.2.19 Flora
  - 2.1.13 Fatigue/Fatigability
  - *2.2.3.1.1.1 Training
  - 2.2.4 Personality Trait

*Implies extreme importance to analysis/model.

2.2.5 Sleep
2.2.6 Work Schedule
2.2.7 Experience
2.2.8.8 Team Coordination
2.4.1.2 Frostbite
2.4.2.7 Trench Foot
3.3.2 Vehicles (as a constant)
3.3.3 Weapons (as a constant)

3.6 Personal equipment
*4.1 Leadership
*4.2 Cohesion
*4.3 Group ID
*4.4 Team Training
*4.5 Operating Procedures
4.6 Shared Equipment
*4.8 Communication within organization
4.9 Task Allocations

*4.12 Reconstitutability
*4.13 Morale/Group Patriotism
*4.14 Doctrine

Step 2 REVIEW DATA

Step 3 REFINE SET OF HUMAN FACTORS TO IDENTIFY THOSE WITH GREATEST IMPACT ON COMBAT EFFECTIVENESS

Step 4 AGGREGATE HUMAN FACTORS EFFECTS

Discriminate analysis of Good versus Bad Leaders

Build Model of Interaction of Leadership and Cohesion

What is Most Important
* Leadership?
* Communication?

Adelphi Method

Step 5 Build and use the next higher level model so as to develop the data needed to help support the decision issue.

8. LESSONS LEARNED

First, understand the question.

Second, know the process being modeled.

Third, document your assumptions.

Fourth, use an interdisciplinary team to analyze or model a mission. Communication between the combat analyst and the human factors engineer is especially critical during model building and results interpretation.

Fifth, examine all aspects of the complete system. Do not apply human factors in a limited way. The best answer is usually a compromise.

9. RECOMMENDATIONS

First, a matrix of the inter–relationships among human factors should be developed to make the human factors based procedure for combat analysis and modeling more efficient.

Second, the hierarchy of human factors should be updated continuously by a single source. To initiate the action, the members of Working Group 2 plus several initiated experts have prepared (since MORIMOC III) a draft "Human Factors Taxonomy" which has been submitted to the AIAA/ANSI and is presently being reviewed by ANSI.

Third, data sources should be developed to fill the voids.

Finally, the aggregation procedures should be expanded to handle all aspects of combat analysis/modeling.

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Articulated Total Body (ATB) Model: This 3–D model predictively simulates the gross motion dynamics of the human body. Primary applications are to ejection and survivable aircraft and road vehicle crash problems. A Generator of Body Data (GEBOD) program also available which provides different size child, female and male, as well as Hybrid II and Hybrid III dummy data sets for the ATB model. Unclassified/Limited Distribution (Qualified Users Only). Cost $1000.00. Available from CSERIAC.

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and performance. Both volumes are very difficult for nonpsychologists to read.

Center for Anthropometric Research Data (CARD Anthropometric Data Base): An on–line database developed to support human engineering design activities. It contains several hundred measurements of the human body across large population samples from numerous published anthropometric surveys. Available data include measurement frequency data and summary statistics, measurement descriptions, and measurement classification by body region and measurement type. Unclassified/Unlimited Distribution. Cost $50.00. Available from CSERIAC.

COMputerized Biomechanical MAN–Model (COMBIMAN): A 3–D interactive computer–graphics model used to evaluate the physical accommodation of a pilot to existing or conceptual crewstation designs. Performs four types of analyses: fit, visibility, reach, and strength for operating controls with the arms and legs. Body size and proportions of the man–model are configurable, using a 35–segment link system that functionally corresponds to the human skeletal system. Unclassified/Unlimited Distribution. Cost $200.00. Available from CSERIAC.

CREW CHIEF: An interactive Computer–Aided Design (CAD) model of an aircraft maintenance technician used to perform human factors evaluations of aircraft maintenance crewstations. CREW CHIEF is an expert system that allows the designer to simulate a maintenance activity using computer generated imagery and determine whether required activities are feasible for a given crewstation configuration. CSERIAC can provide in–house analysis (cost varies) for those who do not have operating systems that support CAD. Unclassified/Unlimited Distribution. Cost $200.00 (excluding system independent version).

Crew Systems Ergonomics Information Analysis Center (CSERIAC): The objective of CSERIAC is to support the requirements of the Department of Defense for incorporating crew system ergonomics in the design and operation of military systems. To achieve this objective, CSERIAC has established a network among relevant knowledge sources on an international scale and develops the media to draw upon this expertise to solve problems, achieve expert consensus, and plan for the most effective use of ergonomics information. CSERIAC uses a range of media to accomplish its mission. Various information products are being developed including handbooks and data books, state–of–the–art reports, critical reviews and technology assessments, research directories, abstracts and indexes, current awareness bulletins, and training materials. In addition, CESRIAC offers a variety of services including responding to technical and bibliographic inquiries, providing support for revision and development of military standards and specifications, and maintaining and implementing computer–based models of human operators. Each year CSERIAC sponsors symposia, workshops, and short courses to apprise scientists and engineers of important developments in crew system ergonomics and to provide opportunities for professional development. CSERIAC maintains the capability to respond to special tasking by government agencies.

Criterion Task Set (CTS): A battery of tests designed to place selective demands on the mental resources and information–processing functions of the human operator. Designed for application to a variety of human performance research areas including workload metric evaluation, assessment of stress effects, and human performance evaluations. Includes nine standardized tasks that tap perceptual, central processing, and response output resources. Unclassified/Unlimited Distribution. Cost $50.00. Available from CSERIAC.

Designer's Associate is a computerized knowledge–based data management system that will aid system designers in locating and interpreting technical data perti-

nent to their needs. Subject matter experts were consulted. The Designer's Associate presents human sensory–perceptual and performance data in a form useful to system designers, particularly aircrew station designers. Topics include sensor acquisition of information (vision, audition, vestibular senses, cutaneous senses, and kinesthesia); perception of motion, posture, and spatial orientation; perceptual organization and spatial awareness; human language processing; information storage and retrieval; attention and allocation of resources; human operator control; target acquisition; human anthropometry; decision making and problem solving; and learning and memory. The data base provides comprehensive information on the capabilities and limitations of the human operator, with special emphasis on those variables that affect the operator's ability to acquire, process, and make use of task critical information. The data base consists of concise two–page data entries on basic human performance data, section introductions outlining the scope of a group of entries and defining special terms, summary tables integrating data from related studies, descriptions of human perceptual phenomena, models and quantitative laws, principles and nonquantitative laws (nonprecise formulations expressing characteristics of perception and performance), tutorials on specific topics to help the user understand and evaluate the material in the data base. Information is presented graphically whenever possible, in the form of figures or tables. The goal is to provide information in discrete units that are easily understood by a user with little expertise in the topic area (Fleger, et al., p. A–159).

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Human Operator Simulator (HOS): Simulates information absorption and recall, mental computations, decision making, anatomy movements, control manipulations, and relaxation. HOS simulates operator procedures by acquiring the data necessary, making a decision, and supplying the appropriate steps to follow. HOS can, in some situations, activate a subsystem if insufficient data are supplied. HOS was developed to assess system operability at early stages of the system design process. HOS enables a design team to investigate system operability under a variety of missions, crewstation designs, operator

characteristics, and environmental conditions without incurring the full costs and delays of building special–purpose hardware and training experimental operators. HOS is implemented as three connected computer programs: HAL, HOS, and HODAC. HAL is the HOPROC (processing language) assembler and loader, HOS is the human operator simulator, and HODAC is the human operator data analyzer and collator. (Fleger, et al., 1988, p. A–71).

HyperText Stack for MIL–STD 1472D (BETA test version): Enables quick location and extraction of specific items of information from MIL–STD 1472 ("Human Engineering Criteria for Military Systems, Equipment and Facilities"). Based on the content of a pre–release version of the "D" revision of MIL–STD 1472. Unclassified/Limited Distribution (U.S. Government organizations Only.) Cost $75.00. Available from CSERIAC.

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MIL–STD 46855D comes out of the Engineering Design and Human Factors Program; contains man–machine design data.

MIL–STD 1472–D was put together by the HEL and contains all types of human factors data including anthropometry, sensory data, and stimuli response data.

Optical Signature, Acquisition, and Detection System (OSADS): A model that calculates air vehicle detectability for man–in–the–loop electro–optical or visual sensor systems. Computes the optical signature of the target under dynamic conditions and does not require the input of estimates. The model depicts a dynamic engagement between an air–vehicle and ground–based threat sensor by simulating lighting conditions and calculating the optical characteristics o the target. Unclassified/Limited Distribution (DoD agencies only.) Cost $100.00. Available from CSERIAC.

Psychophysiological Assessment Test System (PATS): The PATS is a comprehensive microcomputer test system used for the measurement of psychophysiological data. It was designed to address multifunctionality in terms of testing environments and research applications, financial economy, and usability. Its capabilities include data reduction and management, statistical analysis, and interface with simulator facilities. Unclassified/Unlimited Distribution. Available Spring 1990 from CSERIAC.

Siegel–Wolf is a model that simulates task performance of operators in groups of 1–3, 4–20, and 20–99. The model is intended to identify areas of operational overload. Stress is viewed as a basic component of overload. In the course of a simulation, the time that is required to complete a task is drawn pseudo–randomly from a distribution (normal, poisson, Weiball). Flow of simulation: 1) operator encounters a task to perform, 2) task urgency computed (time remaining to complete task sequence), 3) stress computed (as a function of urgency), 4) task execution time drawn from distribution, 5) probability of successful task completion drawn randomly from a distribution, 6) data tabulated and stored, 7) repeated until all tasks are performed, 8) repeated until all iterations are performed, and 9) results reported. (Fleger, et al., 1988, p. A–53).

Shonyo, C. Personnel management in remote, isolated and confined areas. Springfield, MA: National Technical Information Service (NTIS), June 1978. This final report contains a bibliography with abstracts for relevant work reported between 1964 and 1978. It is 45 pages long. To order from NTIS, use number N78–32914.

Subjective Workload Assessment Technique (SWAT): An easily administered subjective scaling method to be used in the cock-

pit or other crewstations to quantify the workload associated with various activities. Postulates a multidimensional model of workload comprising three, three-point dimensions or factors: (1) time load, (2) mental effort load, and (3) psychological stress load. User's Guide and Scale Development software. Unclassified/Unlimited Distribution. Cost $50.00. Available from CSERIAC.

Technique for Establishing Personnel Performance Standards (TEPPS): Computerized technique for estimating the probability of task completion and task performance time. TEPPS is a technique for determining the effects of operator error. TEPPS is designed to "derive specific personnel performance standards with definite relations to system effectiveness requirements." TEPPS allows the human factors engineer to develop personnel performance standards that can serve as yardsticks for comparison with operational performance requirements. Applied in 5 steps using 2 models: Graphic State Sequence Model (GSSM)—essentially a flow block diagram, and Mathematical State Sequence Model (MSSM)—essentially a reliability block diagram. MSSM consists of the dependency and redundancy relationships among task pathways in the GSSM. Computation of the MSSM is done by a computer program in the TEPPS package. (Fleger, et al., 1988, p. A-7).

The User-Assisted Automated Experimental (Test) Design Program (AED): An interactive computer program that enables use of a variety of test designs for test and evaluation programs. AED presents a detailed test design defining the factors and levels for each test run. Current capability of AED includes full and fractional factorial designs, central composite designs, and the definition of alias terms in the design. Unclassified/Unlimited Distribution. Cost $75.00. Available from CSERIAC.

User Assisted Test and Evaluation Methodology Assistant Program (Version 1-TEMAP): A software tool that cross-references critical test and evaluation issues with potential problem-solving methods, techniques, procedures, and guidelines. Intended to organize the system's experimentation protocols, serve as a guideline (checklist) of considerations that must be given to system experimentation projects, and stimulate additional methodological research to improve test and evaluation procedures. Unclassified/Unlimited Distribution. Cost $75.00. Available from CSERIAC.

Zero Input Tracking Analyzer (ZITA) is used to develop a method of predicting shifts in behavior as a result of work load-induced stress. ZITA is designed to test a person's tracking ability. The object in using ZITA is to track a cursor on a 17 x 192 dot matrix display. Using a joystick, the person tries to keep the cursor in a triangle located at the center of the bottom of the screen. The joystick responds through internal device instructions for acceleration, velocity, jerk, and fixed input. ZITA is excellent for testing the stress factors that contribute to a person's tracking skill. For example, it has been used in testing secondary task interference with the primary task. (Fleger, et al., 1988, p. A-139).

CHAPTER IV
REPORT OF WORKING GROUP 3: USE OF HISTORICAL COMBAT DATA

Chair: Eugene P. Visco, Director, US Army Model Improvement and Study Management Agency, ODUSA (OR)

The initial charge for Working Group 3 was to consider the use of historical combat data in modeling and analysis. The charge resulted in the formulation of three broad questions:

1. How can we improve acceptance of historical combat data on the part of decision makers, on the part of modelers, and on the part of model users?
2. How can historical (particularly combat) data be used to help make data from experiments, training, and other non–combat (non–hazardous circumstances) more representative of human behavior in combat?
3. What sources of data remain to be tapped? What are practical criteria that will improve the quality, usefulness and acceptability of historical data? Is there a need for formality, an accreditation process, or responsible authorities or institutions? Or is chaos (the natural state) the best way to proceed for the present?

The focus was on improved definitions of problems and issues for further, more formal analysis and study by the military operations analysis community.

At the outset, we must acknowledge that explicit answers to the three multi–part questions did not result from our deliberations. To a great extent, the process we propose for the community will respond well to questions 1 and 2. To a lesser extent, contributions to question 3 will also derive from application of the process.

An initial set of observations, implications and expectations drove the deliberations of the working group to the structure that emerged. These initial observations are listed; the first three are judged to be the most important; the fourth is speculative but may be important:

- Historical data must influence model design.
- Acceptance must come from good history overcoming myths; some myths may never be overcome.
- Transparency of the analytical processes must be uppermost in the analysts' minds..
- Differences in states (i.e., initial combat, steady–state or experienced combat, end game combat) may require different kinds of analyses.
- Differential human behavior affects combat differentially (e.g., fighting, tactical command and control, higher command and control, rear area support).
- There is need to update the role of historical data in model validation and verification.

These initial observations led to a more general observation that served as something of a beacon for our deliberations. Collectively, we are concerned with much of the current use of historical data. There is a strong tendency to treat historical information as quantification to be manipulated, possibly statistically (e.g., regression analysis) without concern for underlying logics of cause and effect. In place of the often casual application of history, there is a need to use historical data to help provide an understanding of model structures and of causal interconnections among elements of battle. An example that comes to mind is the relationships among casualties, the rate at which casualties are taken by units, morale, cohesiveness, and tactical/operational performance of military organizations (units). And that becomes our central theme.

The incompatibilities between the analyst and the historian and between the analyst and the archivist are often bemoaned. There have been seminars and symposia that express concern and sadness about the incompatibilities, with little improvement in conditions. In our view, a return to the true mixed team approach will go a long way towards eliminating the incompatibilities. Our approach assumes the millennium: the mixed team is back and communication/compatibility reigns as it properly should.

The approach resulting from our deliberations is simplicity itself. It provides a structure for connecting relevant military history battle events to future battle events. It calls for "word pictures" or overview summaries to come from the historian. The work pictures are akin to scenarios, except that the word pictures represent real, as opposed to possible, events; the word "scenario" in a military context is usually associated with descriptions of possible events. The word pictures provide preliminary requirements for data, which data are contained in the archives. The analyst team, including the historian and the archivist, use the relevant data to help construct the new "model" needed to support the analysis of future battle events.

In greater detail, the schema consists of the following steps; the gaming portions of the schema are further displayed in a flow diagram, below:

- The aim (general objective) of the model for future events is specified (e.g., study of battalion operations);
- The context within which the model for future events is to operate is described in terms of the operational roles and METT–T (Mission, Enemy, Terrain, Troops, and Time available);
- Search for comparable historical events is undertaken, using archives and written histories;
- Word pictures are developed, adapted or discovered;
- A "short list" of relevant word pictures are selected on the basis of similarities and dissimilarities (important) between the historical events and the future events; the short list leads to the scenarios needed to help build the model of future events.
- The analytical purposes of the model of future events are defined or stated (e.g., force design, training requirements, weapon assessment); that is, what is the analytical question the model is expected to answer.
- Specific "components" are defined (e.g., firepower, mobility, protection, logistics, command, and human); the components are initially introduced, in general terms at least, by the aim of the model for future events (the first step in the sequence, above).

We interrupt the schema at this point to elaborate on the human component. It is clear that human aspects are contained in all components. Human here means "important" human behavior/characteristics/vulnerabilities that need to be emphasized and separately treated in particular analysis. Human component is not limited to individual characteristics but includes interactions among people in teams, crews and units.

The following gaming steps of the schema are displayed in Figure IV–1 which is a flow diagram of the process as visualized by the group members.

- Key human component elements are defined (quantified and qualified) and are "played" in an existing appropriate war game using existing rules;
- Game results are compared with the detailed description of the comparable historical event; the comparison leads to modification of the gaming rules, not only along the human component but also respecting data and logic; it may be necessary to iterate the process of searching for relevant historical events, emphasizing similarities and dissimilarities;
- Additional historical events can be used, once rules are modified, as validity checks, as addenda to the rules should certain circumstances occur during the game, and as game rule parameters;
- Once reasonable comfort with the revised rules is achieved, the rules can be used to construct the new war game for the assessment of the future events; in addition to the historical influences, the future state of technology, as necessary, is woven into the new game. The new game also incorporates the roles and more detailed descriptions of the environment for the future events;
- The final step is the application of the new war game; the game can be used to construct

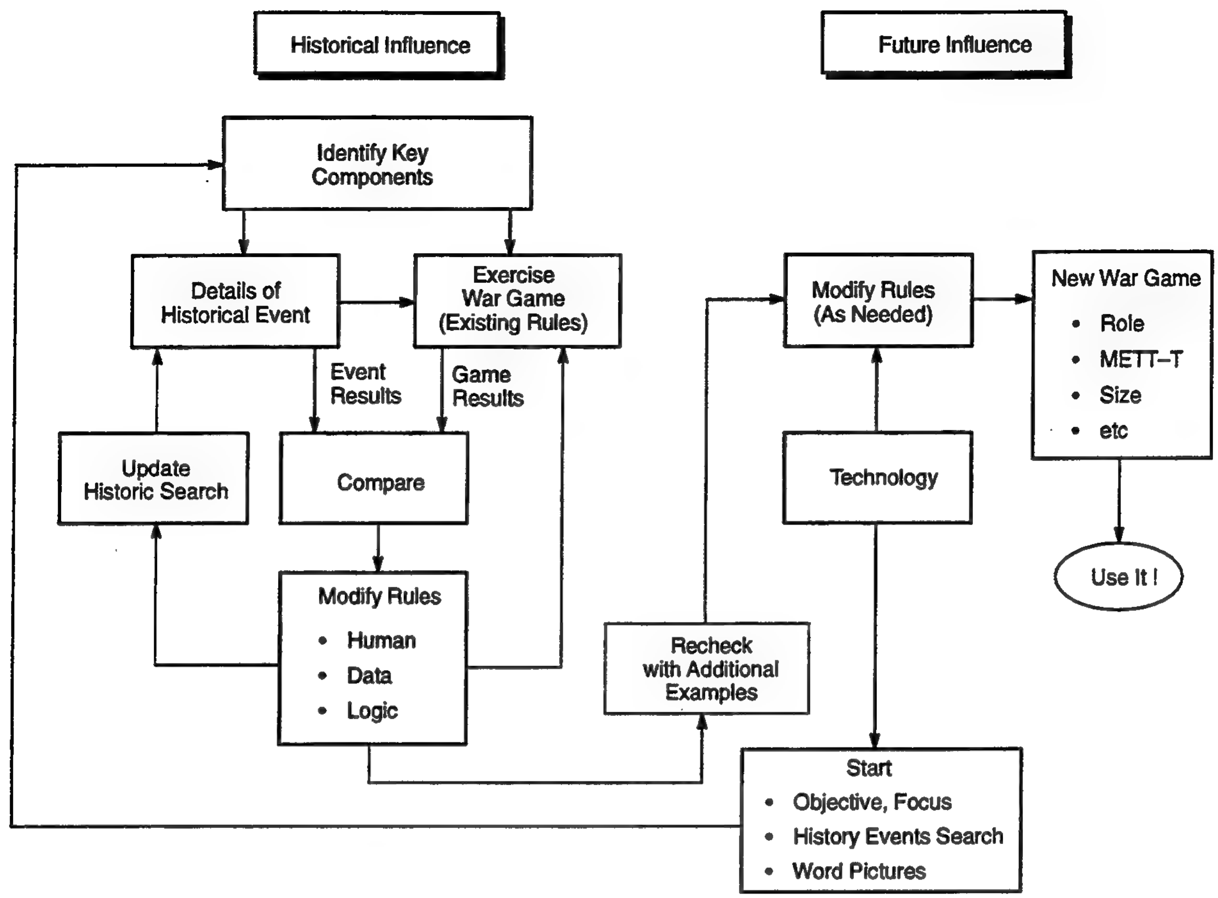

Figure IV–1 SEQUENCE OF WAR GAME DEVELOPMENT BASED ON USE OF HISTORICAL COMBAT DATA

other more or less aggregated and more computer oriented simulations, if desired.

We earlier referred to the mixed team concept. Our view of the mixed team is one including the following kinds of members:

– Operations analyst
– Military historian
– Military archivist
– Physiologist
– Psychologist
– Military commander (warrior)
– Technologist
– Medical officer

The operations analyst is seen as the integrator and generalist and thus should not be a narrow expert on models. The team displayed is focused on the human component considerations. Other team configurations would be appropriate for other component structures.

The deliberations of working group 3 have not led to a comprehensive and tested "model" process for the application of historical combat data to future analyses. We propose here a paradigm, in the strictest sense of that word. It needs further elaboration and more detail. On the other hand, it is ready for use. It is our earnest recommendation that the paradigm be taken up by the community for serious action. In short, our collective experiences tell us that the proposition provides a real step forward in linking historical data into our analytic thinking and is practical at the present time. Thus, the community should review our proposed methodology and, when satisfied with its logic and completeness, start applying the approach, refining and improving it, as insight is developed from its application and use.

CHAPTER V
REPORT OF WORKING GROUP 4: INCORPORATION OF HUMAN PERFORMANCE FACTORS INTO COMBAT MODELS*

Chair: Sally Van Nostrand; Headquarters, U.S. Army Laboratory Command

1. *OBJECTIVE AND SCOPE*

The objective of Group 4 was to:

> "Develop a plan by which behavioral sciences, human factors, and operations research efforts can be steered to ensure that all are working on the same problem (viz., incorporation of human performance factors into combat models) and that the separate research results will be complementary."

The group perceived this as a charter to explore and define the integrating mechanisms for incorporating human performance factors into combat models. We attempted to define both the technical and the organizational structures necessary to successfully embed human performance considerations within combat models.

As the workshop progressed, it became apparent that our focus had to be two–fold. First, the group needed to propose mechanisms by which current generation combat models could be modified to represent human performance factors in a more realistic manner. Since current generation models were, by and large, not designed with human performance as a key variable, they could pose some constraints upon how human performance can be played into them. It is important that human performance be considered in current generation models; accordingly, the group delved into what has been done in this area and what could be done to have current combat models include human performance effects when they are important to the analysis.

Second, the group explored opportunities for future generations of combat models to incorporate human performance. The assumption was made that future generations of combat models would be designed with explicit consideration of human performance factors. Therefore, in considering future models, we felt that we could be more prescriptive. Also, we felt that, by considering some of our prescriptions, future models could provide far more realistic representations of human behavior on the battlefield than can current models.

The group imposed the constraint on their charter that it would focus on ground combat as opposed to air or naval conflicts. The reasons for this were 1) the supposition that ground combat was relatively more man–dependent and less machine–dependent and, therefore, a more critical area for considering human performance and 2) the group itself had substantially more depth in the area of ground combat. Therefore, our recommendations pertain primarily to ground combat simulation.

Finally, we focused on embedding human performance considerations into computer modeling or simulation of combat as opposed to manual war gaming. Many of the concepts and recommendations that we developed would be appropriate to manual war gaming. However, our focus was on computer combat models. At the completion of the workshop, we agreed with one of the suggestions of Working Group 3—that manual war gaming is an excellent medium for gathering data on human performance and decision making in combat since players will often implicitly, if not explicitly, consider human factors in playing the game.

In sum, our charter was to define the technical and organizational mechanisms which would provide the highest probability of success for including human performance into current and future combat models.

2. *FINDINGS*

A simple statement that summarizes our group's recommendations is "Just do it!" The group collectively agreed that there was a sufficient human factors technology base which

*A principal author of the chapter was Dr. Ron Laughery of Micro Analysis and Design.

was compatible with current generation combat simulations. By using this technology base, many human factors considerations could be embedded into combat models today. Furthermore, by making a commitment to consider human performance factors in future combat models, our group agreed that the validity of the human performance aspects of any model can be greatly improved simply by embedding today's human performance modeling technology.

These statements consider the practical aspects of the problem of embedding human factors into combat simulations as well. Given virtually any level of time and resources, some improvements can be made. The additional computational burdens can be kept within fairly tight constraints when needed.

The remainder of this report seeks to substantiate these statements as well as to define what we believe is the most productive agenda to follow. In laying out this agenda, we first discuss several assumptions that were made. Some of these assumptions are well–founded in the experience of the group and some are speculative. We state the basis for each of the assumptions. Then, we discuss the research and development agenda for near term. The near term, as we define it, reflects the inclusion of human factors into the generation of combat models which are currently fielded. Then we present the long term agenda. We believe that, practically, to adequately address human performance in combat models will require the models and software be designed with human factors as an explicitly defined element of the problem. The near term solutions are retrofits and, therefore, may be expensive and never quite exactly what they should be. The long term approach would result in more valid models.

To be sure, there is research and development which should take place to support the embedding of human performance into combat models. However, to restate our basic position, the technology base of human performance modeling is sufficiently mature and internally consistent with current models that it is not necessary to delay any further before making some initial attempts. Borrowing a concept from the book" In Search of Excellence," the time for study and contemplation is over and we should adopt a bias for action. In any case, some consideration of human performance (where it is warranted) is better than the current state of affairs. We are optimistic that significant enhancements could be made to models today, and that future models would benefit from today's experiences.

3. ASSUMPTIONS

In this section, several of the assumptions that were made or formed during the course of the workshop are presented. The basis for these assumptions is also stated.

> **Assumption 1** – Human performance factors are not adequately considered in current combat models.

This assumption was, of course, the underlying reason for the workshop. However, since we should learn from the mistakes of the past, we felt that some exploration of the causes might be worthwhile.

Clearly, human performance factors are rarely considered in most current combat simulations. With some notable exceptions, in current models humans rarely get tired,unmotivated, or make errors, not to mention the host of other battlefield stressors which are not generally considered. There are several notable exceptions that we identified. First, some models now consider the effects of MOPP gear on human performance. The effects on human performance are so dramatic that it is hard to understand why they have been ignored. Second, the AURA (Army Unit Resiliency Analysis) model which was developed and is maintained by the Ballistics Research Laboratory, plays a number of human factors in computing the performance of Army units. Third, and perhaps most noteworthy, the Defense Nuclear Agency (DNA) has embedded the degradation of human performance as a function of nuclear radiation into JANUS models. The DNA work is perhaps most noteworthy in that it demonstrates the feasibility of embedding human factors into current combat models.

Why has human performance been ignored when any field commander would readily attest

to the importance of the soldier as well as the predictability that his performance would degrade more under some circumstances than others? Clayton Thomas provided some historical perspective on this issue. As combat models were first being developed, the data used to define parameters was from actual combat. As such, human factors were actually embedded within the data and, therefore, one could argue, were considered. However, as the potential for higher fidelity models increased, operations researchers constructing the models began to segregate elements of the combat environment and develop models for them separately. For example, what was before simply a combat unit became a series of equipment items and personnel.

As the models increased in resolution, the operations research community asked for data and models on the performance of the lower level elements of combat. At this point, the inability of the human engineering community to provide models of human performance relative to the hardware development community came into play. Until recently, the human engineering community was ill prepared to provide predictive models relating human performance to battlefield stressors, whereas for hardware developers, this was a normal part of doing business. Therefore, while the hardware community was providing the best data and models available, the human engineering community was silent. Following the theme of "do the best with what we have," the operations researchers focused the models on hardware performance and treated human performance as simply unexplained variability.

> **Assumption 2 –** There is a solid base of human performance modeling technology and data which can provide required input to combat simulations.

The consensus of our group was that things have come a long way in the past ten to twenty years. For modeling human performance at the "one vs. one" (e.g., tank–on–tank) level, there is a substantial technology base. Modeling techniques, such as task network modeling and Micro Saint, are mature technologies. Data linking performance to battlefield stressors abound and have, in numerous cases, been translated into forms that would be of use in combat simulations. Techniques for modeling small groups (e.g., few–on–few) are available. In the absence of a better way, the models of large units of humans (e.g., battalions) might use the same methods of aggregation as are used to aggregate the performance of multiple hardware items in few–on–few performance models. What is currently available to incorporate human performance into combat simulations (discussed in Section 4 Recommendations) appears to be an adequate starting point for inclusion of human factors into combat simulations.

> **Assumption 3 –** We are entering an era where new combat models will be needed and, therefore, have an ideal opportunity to build human performance considerations into these models.

The group speculated that there will be a need for new combat simulations over the next few years. The reasons for this can be separated into two basic categories, (1) the changing threat and (2) the inability of current models to respond to questions quickly. The nature of the threat which must be considered in force structuring and establishment of doctrine is rapidly changing. Many of the combat models will need to be revised or at least revamped substantially to study the new threats the US military will face.

However, perhaps more problematic, the current models cannot respond quickly enough to a rapidly evolving threat. As stated in the March 1990 Phalanx by MORS President Edward Brady:

> "The military analytic community seems to be barely participating in these sweeping events. A few key organizations are conducting analyses to gain insight into possibilities or to support decision makers who need to make far reaching decisions with very little time to consider implications and ramifications of such decisions. But much of the community seems to be complacently launching new studies with no changes to basic assumptions. All of this tends to make our community largely a non–

participant or irrelevant to the key decisions made. While undoubtedly change will continue to be a key factor of our lives in the military for the foreseeable future, many decisions need to be made within a time frame which will not wait for use if we leisurely proceed."

We hypothesize that the reason for this is, simply, model development time is excessive and, therefore, often exceeds the time allotted for the decision cycle. For example, to develop a large scale combat scenario takes approximately twelve months, and to construct the associated model inputs takes another six months. In the rapidly changing environment that we now face, these models are rendered useless. Therefore, changes must be made in the way we approach the process of modeling as well as changes in the technology used to construct models. Current advances in software and simulation technology (e.g., the object oriented paradigm) make this evolution in combat model development possible.

Therefore, we assume that new modeling concepts and technologies will be used to develop combat models of the new threat environment. As this occurs, consideration of human performance can and should be an explicit functional requirement of these new models. Our long term approach is aimed at providing the methods, technology, and data for this.

4. *RECOMMENDATIONS AND DISCUSSION*

As stated earlier, we have divided the recommendations into two groups, those associated with a near term solution to the problem and those associated with a long term solution. Associated with each recommendation are potential risks or problems which are identified.

5. *RECOMMENDATIONS FOR THE NEAR TERM—INCORPORATING HUMAN PERFORMANCE CONSIDERATIONS INTO TODAY'S COMBAT MODELS*

We found it helpful to separate the domain of combat models into high, medium, and low resolution models. Our recommendations were split into how to provide input to the high and low resolution models. The mechanisms we would suggest for medium resolution models would depend upon the particular human performance stressors of interest and the combat model. However, the techniques for high or low resolution or a hybrid approach could be used.

> **Recommendation 1** – Incorporate human performance degradation in current high resolution combat models through the inclusion of performance shaping functions.

Working group 4, along with Group 1, identified JANUS as a strong candidate for a model which was amenable to inclusion of human factors for several reasons. First, it is high resolution with the "elements" of the model being at the equipment item level (e.g., an individual tank). As stated in the assumptions section, at the item level the human performance modeling and combat modeling communities "meet." Secondly, DNA has embedded the effects of nuclear radiation exposure on human performance into JANUS models already. Therefore, JANUS has proven to be a feasible candidate.

Our recommended approach is to include what we refer to as "performance shaping functions" (PSFs) into the models, which functions relate human performance and, ultimately, equipment performance to the stressors which were embedded into the model. The basic concept behind the PSF approach is that a functional relationship between human performance and battlefield stressors is defined and then overlaid on top of nominal or average human performance in the battlefield. For example, a performance shaping function relating time for a human to perform a set of activities and time since sleep might be as follows:

$$M = 1.0 - .95\,(.02\,t)^2$$

where:

M is the multiplier on human performance time as a function of time since sleep
t is the time (in hours) since last sleep.

This function is represented graphically in Figure V–1.

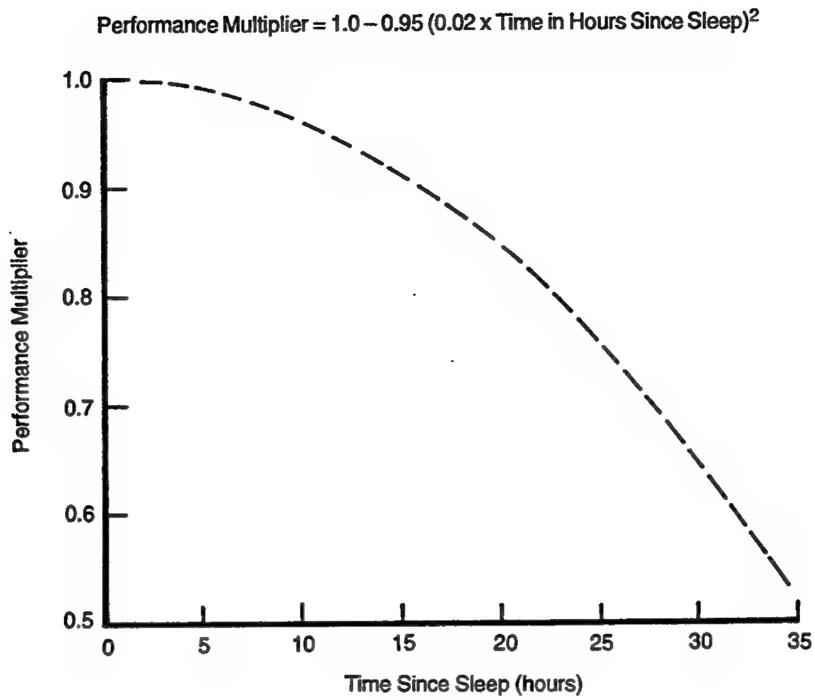

Figure V–1 EFFECT OF SLEEP LOSS ON PERFORMANCE

The concept of performance shaping functions has been around for a number of years. It was conceived as a means for influencing human performance models by Laughery and Gawron (1984)* and as a means for embedding human performance into combat simulations by Van Nostrand (1986). A further example by McMillan and Martin (1989) is provided in Figure V–2.

There are many sources for the development of these performance shaping functions. For some battlefield stressors, these functions have already been developed and implemented in Army models, although not necessarily combat models. We know that such functions have been developed for human performance as affected by MOPP gear, nuclear radiation, body core temperature, and sustained operations, to name but a few. Other sources of data and models are known to be available throughout the Army as well as in the human engineering and behavioral science literature. Several members of Group 4 had direct experience with the development and application of such performance shaping functions.

One source of data for developing performance shaping functions for a specific task is human performance simulation at the individual soldier or small team level. For example, a network model (e.g., Micro Saint) of a small unit of soldiers (e.g., light infantry platoon) performing a task (e.g., hasty defense) could be constructed. A systematic study could run this model to relate performance of the team to the variables of interest. Then, the data generated through these model runs could be used in combat models either through look–up tables or through the development of equations via regression or response surface analysis. Currently, this basic approach is being studied by the Army as a means for relating light infantry team performance as a function of personnel turn-

*References are identified in Appendix B.

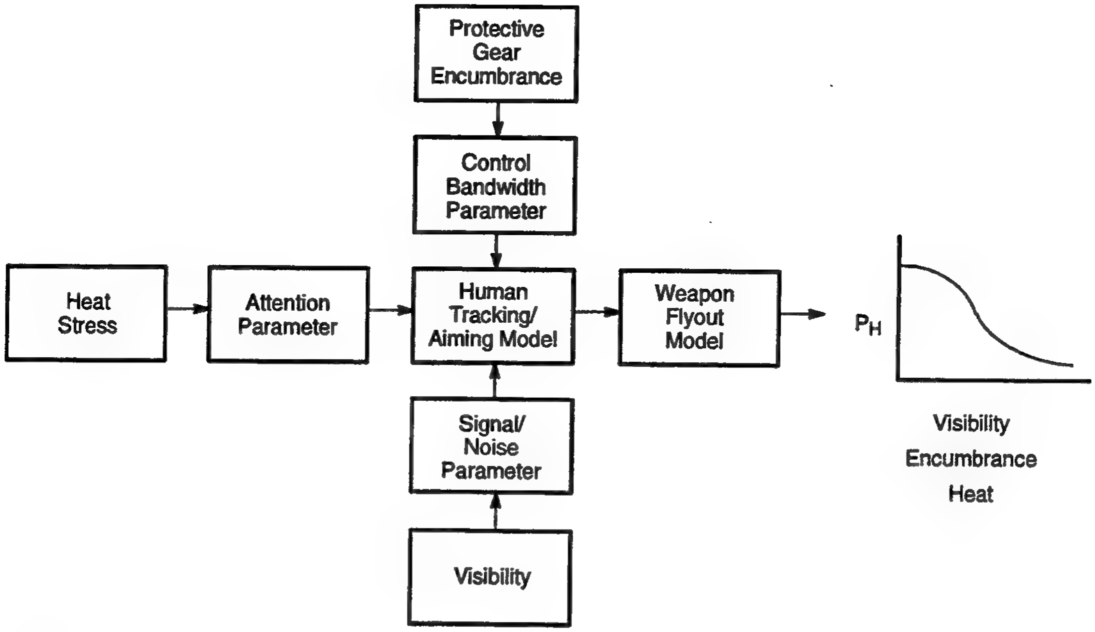

Figure V–2 REPRESENTATION OF STRESSORS IN A WEAPON TRACKING/AIMING MODEL BY PARAMETER MANIPULATION
(FROM MORIMOC II PAPER BY G. McMILLAN AND E. MARTIN)

over and time since training. To extend this into the development of performance shaping factors is both conceptually and procedurally straightforward.

Of course, a hybrid approach is also possible, whereby the network model itself includes performance shaping functions to moderate individual task performance. Then, the network models could be used to predict the aggregate effects of the stressors on overall soldier or team performance.

The bottom line of this approach, however, would need to be simply one or two numbers; (1) the percentage change in performance time and/or (2) the percentage change in performance accuracy. The aspects of the combat models that would then be influenced would be time (e.g., movement time) and the probability of success (e.g., probability of a hit). Of course, the implementation of this approach is not quite this simple, but it is nearly so.

The data sources for developing the performance shaping functions can come from many places. Perhaps the richest source would be the human factors literature. The human engineering community has been studying relationships between stressors and human performance for nearly five decades and a substantial base has been built. Working group 2 focused on how this literature could be organized into a structure usable by combat models and our group believes this structure is sound for the development of performance shaping functions. An illustration of data from various sources being used to generate shaping functions or statistical distributions for use in models is given in Figure V–3.

In addition to the literature, there are data and models being developed by several branches of the US military, perhaps most notably, the Office of Military Performance Assessment Technology (OMPAT) and the Defense Nuclear Agency. They are currently in the process of jointly developing a Performance Information Management System (PIMS) which could serve as an excellent clearinghouse for performance data, particularly data relating human performance to a variety of human performance stressors. The AURA model from the Ballistics Research Laboratory also has

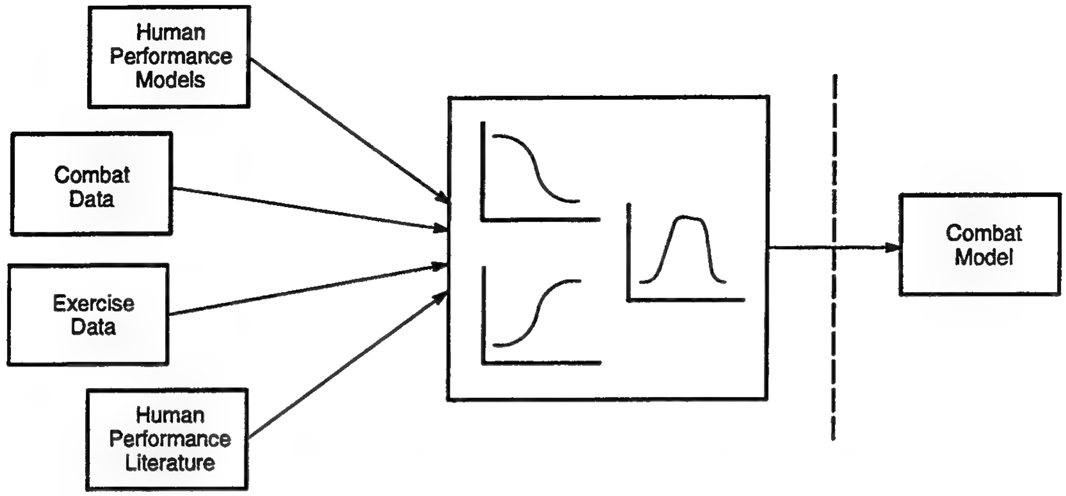

Figure V–3 GENERATION OF STATISTICAL DISTRIBUTIONS AND SHAPING FUNCTIONS OF HUMAN PERFORMANCE FOR USE IN COMBAT MODELS
(FROM MORIMOC II PAPER BY G. McMILLAN AND E. MARTIN)

served as an informal clearinghouse for human performance data.

> **Recommendation 2** – Low resolution "attrition driven" models can be affected by manipulations in parameters of the Lanchester equations.

Many of today's low resolution, force–on–force models are built around the Lanchester equations. Central to the concept behind the Lanchester equations are parameters which define the strength of each of the two combatant forces. In fact, the relative contribution of specific battlefield elements (e.g., mechanized infantry divisions) are related through the amount that each element contributes to a side's "strength."

We propose that performance shaping functions could be used to vary the parameters of the Lanchester equations. Essentially, by changing the parameters of the Lanchester equations, we would be considering the extent to which human factors add to or subtract from effective battlefield strength. For example, a division that has been in contact for 48 continuous hours might count as only half of a fresh division. Essentially, this approach would allow us to consider effective strength of a unit when considering human factors.

6. RECOMMENDATIONS FOR THE LONG TERM—INCORPORATING HUMAN PERFORMANCE CONSIDERATIONS INTO TOMORROWS'S COMBAT MODELS

The following recommendations outline what our group believes are key action items for the inclusion of human performance factors into future combat models.

> **Recommendation 3** – Define a consistent pattern of battlefield decomposition during model development in accordance with the U.S. Army's Blueprint of the Battlefield.

Many combat models, when viewed as software, are in need of update. The earlier reference to the excessive time required to modify them is, we believe, largely due to the need for more attention to software engineering. The current state of affairs is largely attributable to the state of the art of software engineering when these models were initially developed. These models evolved from software which was not developed using structured analysis and design and were not properly documented. As a consequence, making changes to these models is often difficult. For example, the effects of a new tank with different operating

characteristics would not be easy to include in most models since there is no well defined set of software elements that defines "the tank." Even if viewed from the perspective of battlefield functions, the mapping of the functions to the software elements is rarely clear. In addition to the inherent inefficiencies when trying to modify such software, it is difficult to figure out where human factors "belong" when neither battlefield systems nor functions can be isolated.

An exciting new technology that will support the use of consistent methods for battlefield modeling and simulation is object–oriented software design and development. Using object oriented techniques, software modules are developed as "objects" that exhibit defined properties and that send and receive messages to other objects.

This is in contrast to most conventional software which was written using procedural software development techniques. For many reasons, this new approach generally results in software that is more adaptable and reusable, as long as the "objects" that the software represents do not change. In the case of combat simulation, "objects" could include battlefield items such as weapon systems and command and control centers. Then, the software defining these objects would be easily transportable to different simulations.

The approach to modeling combat should be consistent. Towards this goal, we suggest that the design for future combat models reflect the battlefield decomposition defined in the Blueprint of the Battlefield. The Blueprint of the Battlefield has been developed by the Army over the past five years. In the Blueprint, all battlefield functions are defined. The functional decomposition is hierarchical. The lowest level functions would typically be performed by an individual soldier or small group of soldiers. The Blueprint has been designed so that any battlefield scenario can be defined by the functions performed and the sequence in which they are performed. For many of the subfunctions that are performed consistently in the same manner, the sequencing of the subfunctions is included in the Blueprint. It is important to note that the Blueprint has been published as a Training and Doctrine Command (TRADOC) pamphlet (TRADOC Pam 11–9, Blueprint of the Battlefield).

Based upon our review of the Blueprint, coupled with the needs of combat models, we propose that the functional analysis represented by the Blueprint of the Battlefield should always serve as the starting point for defining a combat model. We suggest that by using this as the basis for software development, not only will combat model development be far more efficient, but the points in the software where human performance can be considered will be far easier to find and modify. The following is a run through of how the Blueprint could be used to build scenarios and the ensuing combat models.

Scenario Development. Our perspective of scenario development involves the top–down decomposition of force level missions into unit level missions. The decomposition is carried down to the echelon at which combat modeling is planned. For each unit mission, a concept of the operation is developed (and represented schematically) and the operational and environmental conditions (or ranges) are specified. The concept of the operation consists of a number of activities, including combat, combat support and combat service support. These activities are relatable to, or identifiable with, functions from the Blueprint of the Battlefield. These activities are sequenced and organized to achieve specific objectives, which can include such as achieving attrition, maneuvering to a position of advantage, seizing terrain, disrupting enemy actions, or winning political support of the civilian population.

Combat Modeling. In this step, activities that comprise operations are modeled using available sources of performance data on both equipment (hardware, software) and humans. Human performance data is incorporated into models via performance shaping functions relating the human contribution to performance (or degradation) as a function of conditions (Performance of Activity A = f [condition A, condition B, ..., condition N]). In addition, performance of activities comprising an operation must be related to measures of overall success for the unit operations.

This process of measuring activities within an operation for particular units can be repeated at higher echelons. At each echelon, human performance data would be applied to the activities comprising the operation.

Once again, we emphasize the importance of a consistent structure for decomposing battlefield elements and functions. One of the most frequently stated concerns regarding how to include human factors is "where would they go?" Until we define a solid and internally consistent approach to building combat models, this question will remain unanswered.

> **Recommendation 4** – Recognize that human functions on the battlefield comprise two different types of tasks—action tasks and decision making tasks.

It is necessary to recognize that there are two fundamental types of behavior that humans exhibit on the battlefield. First, humans make decisions and, in doing so, select courses of action that they or other battlefield elements will follow. Second, humans perform actions. They move things (including themselves) and manipulate controls to facilitate a change in the state of the battlefield. These two types of human behavior are fundamentally different in terms of their measures of performance as well as the methods that would be applied to modeling each.

Action tasks are measured and, therefore, modeled by two basic parameters, time and accuracy. How quickly is an action performed and how accurately is it performed are the issues that need to be understood for action tasks.

Decision tasks are measured by the specific decisions made. In other words, what courses of action are charted by the decision maker? It is not usually reasonable to evaluate decisions with respect to how quickly they were made, as long as they are made in time for a useful action to be taken. If a decision is late–coming, then it and the called for action will be overtaken by events. Likewise, we cannot usually judge a decision's accuracy or quality until it is implemented and resulting actions take place. Rather, the task in modeling battlefield decision making is determining what course of action does the decision maker select? If the models were to make the same decisions as the commanders' make, then they would allow us to more accurately evaluate battlefield outcomes. However, in actuality, decisions often have to be made even though some of the needed information may be missing and/or partially wrong. Representing such decision–making environments in models will require innovation.

This recommendation is that we realize the fundamental difference between the two types of human behaviors. Future models should not only identify where human behavior comes into play but, at a minimum, whether this behavior is of an action or decision making nature.

> **Recommendation 5** – For action tasks, build libraries of performance shaping functions linking human performance time and error rates to relevant battlefield stressors.

Earlier, the concept of performance shaping functions was discussed in the context of a way to immediately impact high resolution combat models. In this recommendation, we propose, essentially, to institutionalize performance shaping functions as the means to relate human performance stressors to human actions (but not decision making) in combat. What is not suggested is another clearinghouse for human factors data such as TPDC or CSERIAC. Rather, the suggestion is that a mechanism be emplaced to specifically gather and synthesize human performance shaping functions into a form amenable to future combat simulations.

As discussed earlier, the two key human performance parameters that the performance shaping functions will predict will be changes in time and accuracy. However, there should be a series of performance shaping functions for different task types. For example, it seems reasonable to assume that the relationship between human performance time and a stressor (e.g., sleep deprivation) will be different for cognitive tasks vs. motor tasks. Therefore, one of the first activities must be to develop a standardized task taxonomy. During the workshop, Group 2 prepared such a skill–based taxonomy. This taxonomy includes roughly 50 skill categories largely for individual human behavior. This taxonomy may need to be ex-

panded for group or team tasks, but it is a sound starting point. It is, however, largely theoretical in nature. It may not be obvious to non–human factors specialists which categories map to which military operational tasks. To facilitate the use of the taxonomy, we suggest that this theoretical taxonomy be mapped to the functions defined in the Blueprint of the Battlefield.

The taxonomy represents the dependent variables that the performance shaping functions must predict (i.e., one performance shaping function for speed and one for accuracy for each skill in the taxonomy). The independent variables in the functions are the human performance stressors of interest. The list of key human performance stressors must be compiled. The combined expertise of the human factors community, modeling community, and operational military community should be pooled to develop this list.

From this list of independent and dependent variables that the performance shaping functions should include, the modeling community can begin to compile data and models that can be embedded within the functions. The literature, laboratory, and field data will provide some of the required functional relationships, but we can be certain that not all of the relationships will be defined through these data sources. At this point, the modeling and human performance communities will need to explicitly select and justify one of three options for each undefined relationship; (1) estimate the relationship using subject matter experts, (2) collect data to empirically define the relationship, or (3) choose not to define the relationship and, therefore, implicitly model the stressor as having no effect on the particular human skill.

At this point, the human factors and modeling communities will have built an accessible base of human performance shaping functions. This base will be directly applicable to combat models. Additionally, it will provide guidance as to where future research on human performance on the battlefield is required. This base of human performance shaping functions can be enhanced as the human engineering community continues to gain a better understanding of the relationships between human performance and the battlefield stressors the humans face.

Recommendation 6 – For decision making tasks, commence research on how best to model these tasks in the different types and levels of combat simulations.

As discussed earlier, human decision making tasks are fundamentally different from action tasks in that what we want to predict is not time nor accuracy but the course of action selected. In relatively simple decision making situations, such as selecting a target from several options available, the process and ensuing model of human decision making may be relatively straightforward. For complex decisions, such as higher echelon battlefield command and control, neither the process nor the model may be easily defined.

There is a fairly substantial body of knowledge about how humans make decisions but a more limited technology base for defining how human decision making can be modeled. Some of the more widely known theories include subjective expected utility and the production systems approach proposed by Newell and Simon (1972). The complexity and practicality of these vary widely. Additionally, there is a growing technology base for modeling military command and control, such as that discussed at the MORIMOC I workshop in 1986. It is safe to say that the human engineering and modeling communities have something to build upon. It is questionable, however, how strong this base really is for the problem at hand, modeling human decision making in combat. Yet, it is widely recognized that combat success is largely determined by the decisions made on the battlefield, not just the success in implementing these decisions.

To improve the representation of human performance in combat models, we must model human decision making more accurately. We propose that this is an area that is ripe for both basic and applied research. Any research should be oriented towards the specific problem at hand—modeling battlefield decision making. We believe that significantly improved models can now be constructed from the existing decision modeling technology base. But there is a basic need to develop a consistent, long–term approach or approaches to modeling decision

making, especially as a function of information available and response time available.

> **Recommendation 7** – Map human performance stressors to variables that are perceived by Army personnel as "relevant battlefield mediating variables."

Much of the discussion in this report is in regards to relating human performance to "stressors." In the human engineering community, stressors are thought of in terms of concrete and measurable factors such as "rectal temperature" or "hours since sleep." However, in discussing this with experienced soldiers, the words that emerge tend more towards the esoteric factors such as "motivation" and "fear." While these concepts are difficult to grasp and quantitatively explore, they are universally perceived to be important and, therefore, must be considered.

We hypothesize that these affective human performance stressors could be most effectively handled as mediating variables. In other words, they are not pure independent variables but, rather, they are variables that the independent variables might affect and that, in turn, would affect human performance. The question is what are the relationships between the independent variables and these highly relevant mediating variables and, then, what are the relationships of these variables to ultimate human performance?

The definition of these relationships is another area that is ripe for applied supporting research. We suspect that many useful relationships could be defined with a relatively small effort. Other bodies of literature, such as the social psychology literature, would probably yield applicable data.

In sum, these key variables should not be ignored simply because they are difficult or seemingly non–quantifiable. The combat modeling community may need to include in their models relationships between these variables and performance that are built on sparse and sometimes subjective data. The alternative, unfortunately, will be to ignore some variables entirely, with the implicit assumption being that these variables do not affect performance.

> **Recommendation 8** – Define and adhere to the practical constraints on including human performance in combat simulations.

Finally, our group recognized the need to "keep our feet firmly planted on the ground" in making these recommendations. Modeling, by definition, involves making abstractions from the real world. When we abstract, we leave things out. To be sure, combat models will always leave things out for the sake of expediency and a host of other practical reasons. In defining how human performance should be considered, it is necessary to decide what to include and what to leave out during the process of abstraction.

Many of the ideas developed during the workshop require modeling the human at relatively the same level of abstraction as other equipment items. This, in and of itself, seems like a good guideline. However, it was recognized that there were other potentially constraining factors. For example, it was recognized that all human performance stressors will need to be treated as Markovian processes. In other words, time history of a variable cannot be necessary in order to track only the current value. For example, in tracking sleep deprivation, we cannot keep track of when each soldier has slept over the course of the scenario. To do so would place an unreasonable burden on model size and complexity. Rather, we would track one or possibly two variables which represent the cumulative effects of the soldier's sleep cycles.

There are other unidentified constraints which need to be placed upon the inclusion of human factors into combat simulations and it is expected that these constraints would vary somewhat from model to model. Issues such as which stressors are endogenous and which are exogenous to the simulation would have a substantial impact on model complexity and should be directly addressed before any significant modeling activity begins. What is not needed is a team of well–intentioned specialists bringing a combat model to its knees with undue complexity. With appropriate consideration be-

forehand, this can be avoided so that a useful and appropriate product is developed.

7. RECOMMENDATIONS FOR THE ADMINISTRATIVE MECHANISM FOR IMPLEMENTING AN INTERDISCIPLINARY APPROACH TO THE MODELING OF COMBAT

Once we completed our recommendations on "Just do it!" we realized that in the military setting, with the many organizations that would be involved, a useful addition would be a straw man administrative mechanism. We envisioned this mechanism as a description of a process (who and what will they do) which would facilitate incorporating human performance parameters into combat models. The following recommendations are offered in that spirit. Again, due to the Army–oriented expertise of our group, all recommendations are made in Army terms. The process would probably be the same for the other services, but the organizations involved would be different.

> **Recommendation 9** – The appropriate MORIMOC III leaders should brief various offices and individuals on the findings and recommendations of the workshop.* This could include:
>
> - Deputy Undersecretary of the Army (Operations Research) [DUSA (OR)–sponsor of MORIMOC III]
> - Army Deputy Chief of Staff for Personnel (to include the Director for MANPRINT)

> **Recommendation 9a** – The DUSA(OR) should establish a standing interdisciplinary committee to address selected Army modeling needs.

An appropriate organizational model for this committee is a National Academy of Sciences – National Research Council standing committee. The committee should have responsibility for determining what quantitative relationships between soldier performance and combat–related independent variables have already been identified, and should actively encourage the incorporation of such relationships into combat models, where appropriate. In addition, the committee should identify research which needs to be performed to increase the operational realism of combat models, and should serve as a formal advocate for such research.

> **Recommendation 9b** – The committee should formally identify each research need by developing and publishing a document called a Modeling Research Need (MRN).

This document would be a one or two page description of a particular modeling related need for which human performance research is currently required. An example of a problem that could serve as the basis of an MRN is the need to establish the quantitative relationship between soldier performance on combat tasks (e.g., acquiring targets, operating a weapon system) and wearing MOPP gear. The impact of time since sleep could be an additional parameter.

> **Recommendation 9c.** – In addition to developing MRNs, teams within the committee will recommend methods for incorporating human performance parameters into current combat models, develop specifications for new combat models, and develop or outline a prototype new combat model.

We recognize that recommending methods for incorporating human performance parameters into current combat modes would be a short–term solution which would essentially involve patching up current attrition–based models. However, it is probably necessary to begin here so that the value of including human performance parameters can be studied prior to committing resources to developing new combat models. In any event, new combat models will be necessary, if only to enable analytic agencies to adapt to the changing world environment. This committee would participate in developing the specifications for all new combat models so as to ensure the incorporation of parameters, such as human performance, which are currently not well represented in combat models. Finally, the

*This to include outputs of all five working groups.

committee will develop a prototype combat model, or outline the structure of a model, which would meet the specifications. All products developed by this committee should be provided to the DUSA (OR) (and any other sponsors who might desire them).

> **Recommendation 9d** – The committee should be composed of representatives from the following organizations (as a minimum):
>
> **Modeling** – DUSA(OR), Concepts Analysis Agency, TRADOC Analysis Center, Army Materiel Systems Analysis Activity
>
> **Human Performance** – Army Research Institute, Human Engineering Laboratory, Walter Reed Army Institute of Research, Army Research Institute of Environmental Medicine, Defense Nuclear Agency.
>
> Others – Army Intelligence Agency.
>
> **Recommendation 9e** – To keep the size of the committee at a level conducive to operating as a working group, each of the organizations should be limited to one representative.

We further recommend that each representative be appointed by the head of his or her organization. Characteristics that must be considered in the appointment are: (1) being knowledgeable in a relevant subject matter area; and (2) motivated to serve as a member of such a committee.

We anticipate that the committee would formally meet several times a year, and that individual members would also spend time on committee related work at their parent organizations. We also anticipate that the teams within the committee would meet as working groups for longer periods of time (perhaps 2–3 weeks each time) to address the specific issues identified in this report.

If several such committees are established—as for each of the services—provision should be made to ensure the interchange of MRNs, technical reports, and ideas among the committees, as appropriate.

Establishment of the MORIMOC interdisciplinary committee(s) and the publication of MRNs would serve several purposes:

- Facilitate the systematic identification of human performance issues and problems which need to be addressed in order to improve the operational realism of models.
- Provide formal documentation of human performance research needs, to which research organizations could formally respond and incorporate into their work programs.
- Create a process by which members of the operations research and modeling community could interact with members of the human performance research community and thereby achieve a cross–fertilization of ideas which could ultimately lead to an understanding of, and ability to predict, the performance of soldiers and systems in combat.

8. SUMMARY

In Summary, working group 4 believes that there is a sufficient technology base which can be tapped for including human performance considerations into combat models. Human engineering has improved to a point where useful and valid input can be provided and the combat modeling community has come to recognize the need for this input. Furthermore, if new generations of combat models are developed to address the evolving threat and future scenarios, then the opportunity for including human performance considerations is ideal. Over the years, additional research may be required to enhance these capabilities but, for the moment, we should "just do it" and learn what we need to learn.

CHAPTER VI
REPORT OF WORKING GROUP 5: COMBAT MODELS INCORPORATING HIGHER LEVEL BEHAVIORAL FACTORS

Chair: Professor Wayne Hughes, Capt. USN (Retired), Naval Post Graduate School

Working Group 5 had as its objective the development of a philosophy for and an approach to structuring combat models in which the driver is achievement of military objectives rather than calculation of relative attrition scores for the opponents. Thus the new models would be more supportive of decision issues. A focus in this new type of combat model was to be placed on higher level human performance factors (e.g., leadership, cohesion, and benefits of battle experience and training), especially at company, battalion, and division levels, to the extent that they may effect battle outcome.

Discussion

The group commenced its deliberations with the axiom that achieving a military objective requires domination of the enemy, and that domination is achieved by means of combat or the threat of combat. Domination was defined as the condition wherein one military force imposes its will on an opposing force, thereby eliminating all options of the opposing force.

A perspective on the application and effectiveness of military force was developed and is related in the following.

A military force is an organization of two different kinds of elements—the command and control elements and the executing elements. Executing elements are of two types—those that perform all the physical actions that occur on the battlefield and those that directly support the elements on the battlefield. The primary battlefield elements are the combat maneuver elements (which includes infantry, armor, cavalry, and attack helicopter forces). These are sustained by combat support elements (e.g., fire support, air defense, engineers, intelligence), combat service support elements (e.g., maintenance, supply, medical), and tactical air support.

The command and control elements are responsible for integration of all the force elements in a unified effort against the enemy to achieve the military objective. The command and control function is performed at all echelons by teams which plan, prepare, and supervise coordination and synchronization of all available combat executing elements in the action against the enemy force.

The combat potential of a military force is the latent capability of that force to achieve results in combat. The realizable capability of a military force that is available to the force commander is termed combat power and is less than the force's combat potential because of such factors as (see Figure VI–1):

- Applicability – does the force comprise the correct resources for the combat mission to be performed? (e.g., is the force primarily armor and the mission is in mountanous jungle?)
- Availability – the status (condition, location) of the force's troops, vehicles, weapon systems, and supplies
- Organization – include hierarchy and arrangement of military force elements, lines of command and communication, and tactical doctrine; critical to efficient conduct of operations and maximizing combat power.
- Battle capability – extent to which training and battle experience of the leadership and troops provide effectiveness in combat.

Increments of combat power are delivered by executing elements of the military forces—tanks of a brigade, riflemen of an infantry company, crews of an air defense system, etc. The degree to which increments of combat power contribute to battle outcome is a function of how effectively they are applied by command in coordination with other executing elements (at the right time and in the right place).

The effectiveness of combat power of a military force during battle is impacted by several additional factors (see Figure VI–2). First are the enemy's responses to the presence and actions of the military force engaging (or

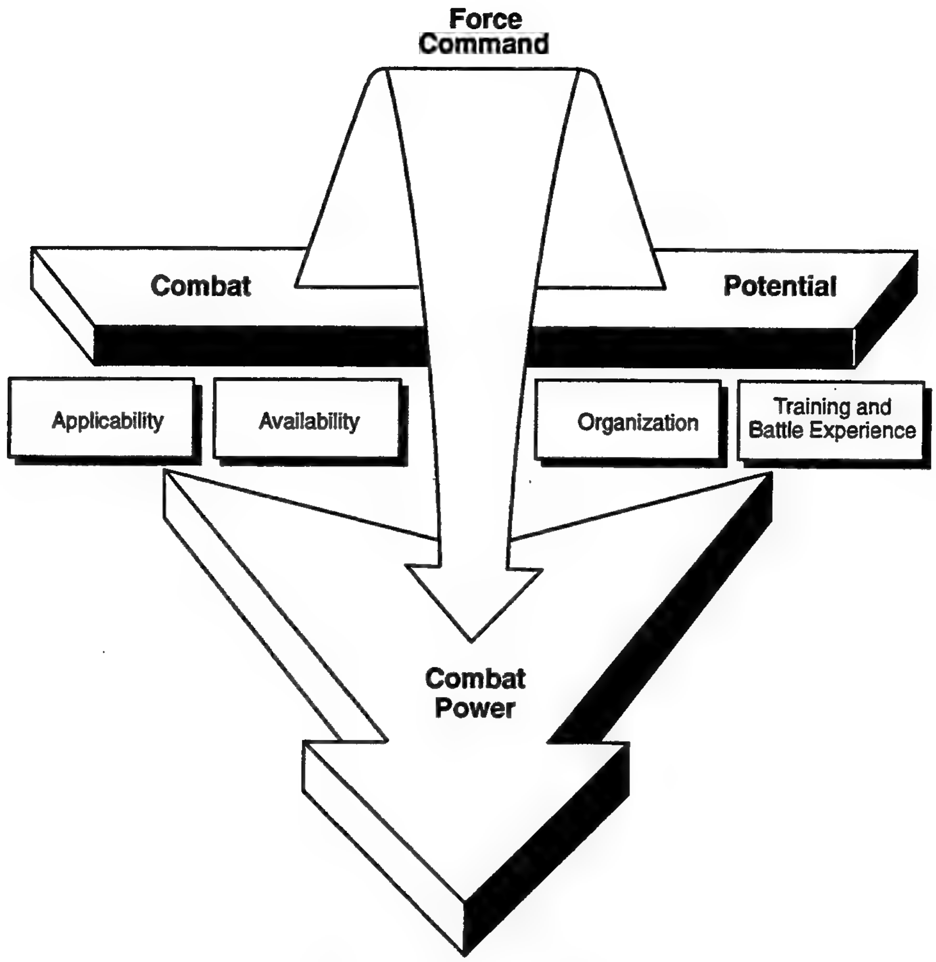

Figure VI–1 FACTORS DETERMINING COMBAT POWER OF A MILITARY FORCE

preparing to engage) them; these responses include aimed and suppressive fire, passive defense (e.g. prepared positions, mine fields), and active responses such as increasing the defensive forces and attacking communication and supply lines of the attacker.

Second is uncertainty, defined here as a state of doubt about the combat situation. This condition can be caused by faulty intelligence before and during the battle regarding enemy strength, positions, and intentions, and (during battle) by degraded observation and communications capabilities, resulting in incorrect, delayed, and missing information, all of which degrades command decisions at all levels.

The third factor is termed "friction of war"and is that factor which turns even simple military operations into difficult tasks. Examples include precipitation extremes which can make roads and bridges impassible and flying impossible, equipment that breaks down and no repair parts are in reach, friendly fire being directed by mistake on own forces, and combat units arriving to late or at the wrong location to be useful.

Last, but not least, are the human performance and behavioral factors, especially as influenced by the battle environment–battle intensity and duration/exposure to NBC weapons effects, extremes of weather/terrain, and isolation from other members of the team. At the individual and small unit level, these factors can induce fatigue, fear, confusion and demoralization. At higher levels, other human factors appear to be very important in that they can improve or inhibit soldier (individual, team,

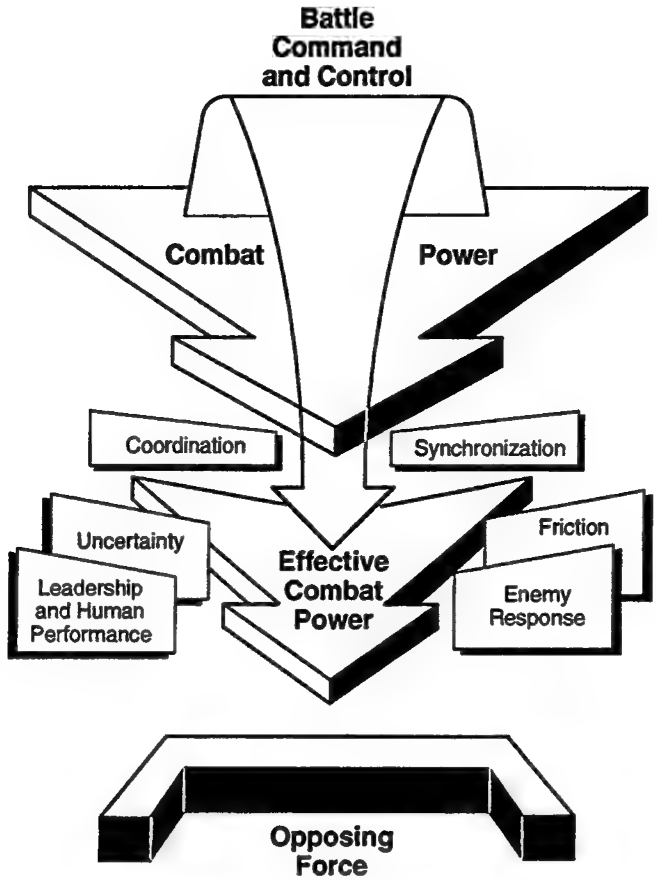

Figure VI–2 FACTORS IMPACTING COMBAT POWER AND ITS EFFECTIVENESS

large unit) performance, depending on their quality. These factors include leadership at all levels, battle experience, and training and conditioning. These, more than any other human factors, impact group cohesion, morale, and battle performance.

Based on these considerations and their collective backgrounds, the working group defined a conceptual approach to modeling of two–sided combat in which achieving a military objective is the driver. The approach is based on several theses which are stated and discussed in the following.

Thesis I: the primary tool needed to help make better decisions concerning combat is an understanding of its nature in the form of an organized body of knowledge (theory). The secondary tools, always suspect in the absence of the primary one, are combat models. The aim of the former is descriptive: theory's purpose is to say, thus and so are true. The aim of the latter is prescriptive, whatever the practical limitations: a model's purpose is to say this is likely to be the case, so do such and such.

1. The aim of theory is synthesis; therefore it is general, with very limited particular application. The aim of a model is particular; therefore it is limited in range and is focused in applicability. A model which endeavors to be very comprehensive is a mixture of the two motivations and often is a bad compromise.
2. The theory that is needed is one that provides understanding of combat–such as how military forces fight and win or lose and why battles have the outcome they do—and how the quality of leadership and troop training impact force effectiveness in battle. Such knowledge is needed as the basis for development of combat models driven by military objectives.

3. Since human factors pervade combat, they should be accommodated in the theory. It is probably too much to expect that all human factors will be incorporated in a practical, decision—oriented model; in the strict sense all could not possibly be incorporated. One aim of theory should be to help modelers and their clients understand which human factors are essential and which are not, and, thereby, to assess whether they should be included or not in a given model application.
4. As with all theory, the theory of combat will contain primitive, or most basic, concepts that are thought to be so self–evident as to be axiomatic. These are not empirical guides to action, like the principles of war, but statements of observed "fact," held to be true in the theory. An example is: combat is deadly interactions between military forces which produce results on a battlefield. This minimum set of "facts" or axioms form the basis on which to build understanding of key relationships and interactions. One test of the theory is internal consistency. The other, which is not often likely to be quantitative scientific validation, is a corroborative process that shows the theory to comport with observation, including combat in history.

Thesis II: The goal of combat is defined by the command element of a military force and is achieved by dominating the enemy (with or without battle) by means of the deployment and activation of the military force's combat power by its Command element.

1. Domination, the imposition of one's will on an enemy, is the preferred term because it can be applied at any level of aggregation of military force from the strategic, to the operational, to the tactical, to the individual soldier's level.
2. Building blocks are formed by the appropriate definition of participating elements as to the degree of their aggregation. Each element on both sides is in a state, which in principle is a vector of all physical and cognitive attributes of the element (see Figure VI–3).
3. Domination is achieved through the alteration of the state of the enemy, both cognitive and physical. One change of cognitive state of an enemy would be his recognition of (or belief in) our ability to inflict unacceptable casualties upon him, whether or not he has brought our ability to a test. One change in physical state is his destruction.

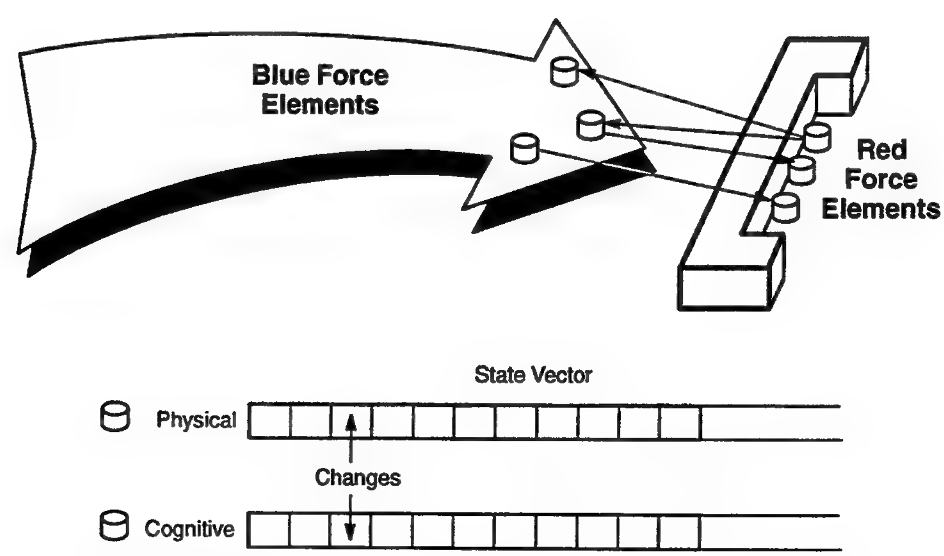

Figure VI–3 ELEMENTS ACT ON ELEMENTS TO CHANGE STATE VECTORS

4. When engaged in battle, our force displays an effective combat power which is less than the combat power activated by our command element.

Thesis III: Command and control is the process of activating and deploying organized military forces, and coordinating and synchronizing the forces' activities (thus transforming combat potential into combat power). The operational aspect of command is to distribute the combat power

- spatially – positioning portions of the force's elements at selected locations.
- temporally – positioning of the forces in a certain time or sequence.
- Functionally – assigning the force's elements to accomplish specific tasks.

Performed correctly, the result is a proper distribution or allocation of combat power against the observed or anticipated distribution of the enemy's combat power, so as to achieve a military objective.

Thesis IV: Combat power is activated from available combat potential, which itself is no greater than designed combat potential. Combat power, a rate of delivery, is governed by total available potential, a quantity, and by choices made by command in the manner of activation.

1. Combat power is less than the available combat potential primarily because:
   a. Command applies a portion of the force for other than their primary function (e.g. armored forces applied in mountainous terrain or use of AAW ships against submarines).
   b. It is usually the case that combat potential cannot be applied when desired during combat because the enemy will destroy some of the potential before it can be employed.
   c. There is a decrease in both group cohesion and individual effectiveness of a force due to enemy resistance, causing fear, surprise, confusion, etc.).
   d. Uncertainty exists about the combat situation, especially within a command element, created by enemy activities (deception, jamming, attrition of information gathering and communication systems).
2. In addition, not all actualizable potential will be realized because of what has been termed "friction of war."

Thesis V. Command's preparation of actual combat potential from the raw material of designed combat potential; command's activation of actual potential to create combat power: the attenuation of combat power due to friction and resistance, the consequences of which yield effective combat power; and the battlefield results that stem solely from effective combat power; all combine to form a general, foundational paradigm for purposes of designing and testing combat models, when the paradigm is treated as a two sided, force–on–force phenomenon.

1. In general terms, both the means and the ends are specified.
2. In general terms, the factors including the human factors impacting on the transformation of the means to the ends, have been specified.
3. The precise quantitative relationships are left unspecified in the paradigm.
4. When the quantitative relationships are specified for one side (say just our side), this will yield a measure of our combat power in which the relative influence of factors under our control are calculable.
5. When the quantitative relationships for the other side and for the battlefield environment are added, this will yield a measure of combat effectiveness from which two–sided results may be estimated and inferences extracted.

A Design Approach: The quantitative relationships and the dynamics of the interaction of military forces can be thought of as imbedded in a quantitative, Object–Oriented Design. The goal of such design is development of an accurate and complete representation of the problem domain. Therefore, it is suggested that Object–Oriented Design be used in the design of the new combat model. The following relationships, in conjunction with the foregoing six theses, are defined as a starting point for the model design effort.

1. The basic structural idea is that objects send messages to each other which cause the receiving object to invoke an internal procedure resulting in some activity and/or change of state.
2. Each military force can be considered an object which is in a state and which exchanges messages that are units of combat power.
3. Each object can be subdivided into sub–objects, each of which has some or all the characteristics of the parent (aggregate) object plus other characteristics unique to it (for example, headquarters object and infantry battalion object).
4. In this application, sub–objects are of two classes: operational and command.
5. Upon receipt of an enemy "message" (physical such as gun fire, or cognitive such as maneuver onto a flank) an object element changes its physical or cognitive state or both.
6. Upon receipt of a message, an operational object invokes an internal procedure and executes an activity constituting an action (physical) event which modifies its state.
7. Upon receipt of a message, a command object invokes an internal procedure and executes an activity constituting a cognitive event which modifies its state; in this way cognitive events achieve the same status as action events.

This presents the results of the thinking and deliberations of Working Group 5. Substantially more effort is required before the overall structure and formulation of a military objectives–drives combat model can be defined. However, it is felt that a good start has been provided, one based on the theory of combat, and one which includes consideration (as warranted) of such usually neglected "soft factors" as higher level human performance, friction of war, and uncertainty. It is hoped that what we have accomplished and recorded here will provide the basis for development of combat models which serve the multiplicity of needs posed by military decision makers.

Appendix A
TERMS OF REFERENCE: MORIMOC III

8 November 1989

TERMS OF REFERENCE
MORS WORKSHOP

"Human Behavior and Performance as Essential Ingredients in Realistic Modeling of Combat"
(MORIMOC III)

Background

The performance of humans in battle environments, functioning as individuals, crews, or in units, and the ability to model or account for the influence of humans on combat operations are subjects of long term interest to members of the operations research, human factors, and behavioral sciences communities. In addition, these subjects are of interest to military decision makers because of the potential impact of the human behavior in combat on the bases they employ for their decision making.

Over the past decade, many DoD-sponsored activities, including the MORS-sponsored MORIMOC I in February 1986, examined the shortcomings and needs of combat model building and use for supporting such as war planning, training, procurement, and logistics decisions. A unanimous finding of all these activities was the lack of accounting for the effects on battle outcome of human actions and performance in the combat environments at all levels of the opposing forces. Yet the human element has overriding importance in all battle operations. The weapons effectiveness and combat analysis/modeling efforts must account for the capabilities and the degradations of the combatants' performance, and must reflect these effects at the individual, crew, and unit levels, as appropriate, because of their influence on the outputs of such efforts.

In response to the needs, MORS took the initiative by conducting the MORIMOC II Mini-Symposium in late February 1989. This program, which was held at the Center for Naval Analyses in Alexandria, Virginia, was a first step in performing a multi-disciplinary program to develop the understanding needed to ascertain when and to what extent human performance (capabilities, limitations) can affect combat model outputs used to support resolution of decision issues, the extent to which such effects must be accounted for, and how human performance can be included in modeling of weapons effectiveness and combat. The particular objectives of this mini-symposium were to:

1) Develop an information base on the present status of modeling of human performance in combat and the effects on the conduct and outcome of battle, and

2) Provide guidance and direction to the structuring of the work areas for a planned sequel, the subject MORS Workshop termed MORIMOC III.

From the standpoint of the first objective, the more than 50 papers offered for presentation at the mini-symposium (of which 34 were selected) provided substantial evidence of an existing information base in the areas of:

1) Methods for quantifying potential performance degradation of individuals and weapons crews in combat environments, based on data from combat, weapons tests, and real-time simulations.

2) Techniques for estimating environmental and workload effects on human performance.

3) Availability and utility of combat data for modeling and analysis inputs.

4) Approaches for including human performance factors in combat models and results obtained from recent analyses of combat effectiveness.

The 34 papers presented plus the formal remarks of the discussants of the papers have been assembled into a draft Proceedings of MORIMOC II.

A unique feature of MORIMOC II was the participation by representatives of several of our NATO allies (SHAPE Technical Centre, Canada, France, Great Britain, The Netherlands, and West Germany). Significant contributions to the information base cited above, including interesting perspectives on approaches to the MORIMOC II problem, were provided in papers presented by several of these participants.

As to the second objective, the cumulative information provided by the many papers and discussions comprising MORIMOC II gave much insight into various problem areas for which understanding and methodology need to be developed to support the solution of the MORIMOC II/III problem. A selected set of these problems will serve as the agenda for the MORIMOC III Workshop working groups.

Objectives

The objectives of this MORIMOC III Workshop are:

1) To develop understanding of the extent to which human performance and behavior affect combat and military decision issues, thereby becoming "essential ingredients" to military decisions.

2) To define approaches to incorporating human performance factors in combat models/analyses used to support various decision issues.

The specific tasking for the individual working groups making up the workshop will be defined so as to focus each group's efforts on selected aspects of these objectives.

Scope

The workshop will focus on five problems, each of which has been identified and defined following a review of the presentations and discussions of MORIMOC II and the collective experience and background of the mini-symposium chair and session chairs. The working group participants will be divided into five groups, with each group's membership being selected as appropriate to one of the problems. Each group will be assigned one problem and will focus on working out an approach to the solution of that problem.

PROBLEM 1

For what decision issues and at what levels are human performance factors "essential ingredients" to military decisions?

a) When does human behavior affect combat and military decision issues?

b) Which human performance factors (hpf) have how much effect and in what circumstances?

c) To what extent can existing combat models accept (or be modified to accept) near-term hpf data bases and provide hpf-influenced outputs for support of decision issues? (Consider only those cases where hpfs have meaningful impact on the decision issues.)

PROBLEM 2

Develop understanding on the broad issue of human performance factors and hpf data bases, considering such standpoints as:

- o How to aggregate/desegregate data validly? When needed? What are the limits?
- o As level of aggregation increases, which factors matter less? More?
- o What are the needs for interpretation of unit or group behavior for use in combat models/analysis?

PROBLEM 3

Consider the use of historical combat data in modeling and analysis.

- o How can the acceptance by decision makers of the use of historical combat data be improved?
- o Can historical and combat data be used to provide effects of stressors (e.g.) on non-combat data from experiments, training? How?

PROBLEM 4

Develop a plan by which behavioral sciences, human factors, and operations research efforts can be steered to ensure that all are working on the same problem and that the separate research results will be complementary.

Consider specific needs such as:

- o Specialized support from psychologists
- o Providing effective communications among the research efforts
- o Supporting development of input data

PROBLEM 5

Develop a conceptual approach to incorporating higher level behavioral factors in modeling/analysis to support decision issues. These might include leadership, unit cohesion, communication, training, battle experience and morale.

Consider:

- o Combat models in which opposing forces are composed of multiple units and group phenomena are dominant.
- o Combat models driven by military intentions and capabilities rather than by force ratios or attrition.
- o Development of the needed group performance data bases.

The discussions and the data used in the analysis of each problem will be at the unclassified level. MORIMOC II kept its material unclassified and there was no sacrifice of coverage or quality. This same rule will hold for this workshop, thereby allowing (1) our NATO Allies to participate and (2) the meetings to be held in an unclassified facility.

Agenda

The Workshop Chair will develop a detailed agenda which will be sent to all invited participants along with a read-ahead package of selected materials. The Workshop will be held on March 26 - 29 (Monday through Thursday) 1990, at the Center for Naval Analyses in Alexandria, Virginia.

The Workshop will start with the Chair describing the Workshop organization and introducing the chairs of each of the five planned working groups. Then the Workshop Chair will (1) outline the objectives of the Workshop, (2) describe the problem area assigned to each working group so that each participant will have a grasp of how each group's efforts will contribute to the overall product, and (3) review the agenda to be followed over the four-day effort. The majority of the first three days will be given to deliberations, analyses, and assessments, as appropriate, by the participants comprising each working group. The last day will be devoted, for the most part, to reporting of findings, integration of results obtained, and outlining of a draft paper/briefing on the workshop highlights.

A mixer on the first evening and a dinner on the second evening are planned so as to help our multiple-disciplinary group become better acquainted.

Workshop Methodology and Output

The five problem areas to be addressed by the working groups were identified above. The most appropriate source materials to be read by each participant in preparation for contributing to the Workshop's objectives are in the MORIMOC II Proceedings. A copy of this material will be made available to each participant when he is invited to attend the Workshop.

The chair for each working group will develop and provide a work agenda for his group which focuses on the specific problem assigned to that group. This agenda may include a suggested approach to consideration of the assigned problem and/or selected examples which illustrate and serve as a test-bed for the group's deliberations and analyses. The chair may also prepare and provide a read-ahead package for the members of the group or some work-ahead tasks to be thought about prior to convening the Workshop.

There will be a certain amount of parallelism and overlap among certain of the five problem areas. Because of this, and recognizing that many of the participants will have knowledge and experience in more than one of these related areas, it is planned to rotate several members from each working group into another group on the third day. The purposes of this "musical chairs game" are to provide a fresh insight into each problem by the new members brought into each group, have the new members apply applicable inputs/results from their original working group problem to their new problem (cross-fertilization), and provide for some critique of the approach and results obtained by each working group while there is time to modify or improve their product. The group chairs will not rotate.

The Workshop will provide as products an unclassified formal Workshop Report in which the major deliberations, analyses, and results reported for each of the Workshop problems will be documented in a storyboard-type format. Several articles summarizing the results of each working group's activities will be published in PHALANX. A vugraph briefing of the major findings relative to the five selected problems will be prepared immediately after the Workshop and will be offered to the MORS sponsors. Finally, an oral presentation by the chairs of the Workshop and the work groups will be given at a General Session of the 58th MORS Symposium to be held at the U.S. Naval Academy, Annapolis, Md, on June 12 - 14, 1990.

Workshop Membership

The Workshop Chair will be Stephen A. Murtaugh, of Calspan Corporation. Mr. Murtaugh, a former MORS President and three-term elected Director of the Society, was Chair of the MORIMOC II Mini-symposium held in February, 1989, and was an active participant in the first MORIMOC Workshop.

It is planned that the Working Group Chairs will be the same people who were the chairs of the five technical sessions of MORIMOC II:

Mr. Vernon Bettencourt, Potomac Systems Engineering,
Capt. Wayne Hughes, USN (Ret'd), Naval Postgraduate School,
Dr. Michael Strub, US Army Research Institute Field Unit, Ft. Bliss,
Ms. Sally Van Nostrand, US Army Laboratory Command,
Mr. Eugene Visco, ODUSA (OR), The Pentagon

Participants will be invited based upon their experience and capabilities related to the specific problem areas, as they provide in their application for invitation. Priority will be given to those who were active participants in MORIMOC II because of the knowledge gained which will be helpful in this Workshop. The Chair will control the number of participants to approximately 40 to 45. As in MORIMOC II, participation is expected by representatives from our NATO allies, including the NATO SHAPE Technical Centre.

Proponents and Fees

The MORS will sponsor this focused Workshop as it did the two preceding MORIMOC activities. Similarly, the proponents of the MORIMOC II mini-symposium - The Deputy Undersecretary of the Army, Operations Research, and the Assistant Chief of Staff, Studies and Analyses, Headquarters US Air Force - will continue as the proponents of this Workshop.

The fee for government personnel is **$125**, and for non-government personnel is **$250**, to defray the administrative costs of the Workshop. Each participant will receive a copy of the Workshop Report.

MORS
101 S. Whiting Street
Suite 202
Alexandria, VA22304

REQUEST FOR INVITATION TO MORS MORIMOC III WORKSHOP

Name: ______________________________

Rank/Title: ______________________________

Organization/Company: ______________________________

Address: ______________________________

____

Telephone: ______________________________

Did you participate in MORIMOC II? If so, what was your contribution?

____

In which of the five problem areas of this workshop do you have experience?

____

Tell us about your experience pertinent to the workshop problems so that we can make a considered judgment as to your invitation and assignment.

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Indicate your priority order of preference for assignment to a problem.

____

Use another page, if needed, to respond fully to these questions. Mail this form to the MORS office no later than 8 December 1989. Do not send the registration fee at this time.

Appendix B
REFERENCES

The following eight references are all from the Proceedings of the Mini–Symposium "Human Behavior and Performance as Essential Ingredients in Realistic Modeling of Combat – MORIMOC II", Military Operations Research Society, Arlington, Virginia, February 1989.

1. Research Into a Conceptual Framework for Representation of Human Factors in Combat Models: W. Peter Cherry and Irving Alderman.
2. Discussion of Papers Presented in Session IIIA: M.G. Ennis Whitehead, USA (Retired).
3. Fatigue of Soldiers in Battle: MAJ Werner Siemon and Helmut Wollschlager.
4. Effects of Ionizing Radiation on the Performance of Selected Tactical Combat Crews: George H. Anno and Michael A. Dore.
5. Tactical Deterrent Effects Model: George Schecter, James C. Richards, and Henry A. Romberg.
6. The Fundamental Information Base for Modeling Human Behavior in Combat: COL Trevor N. Dupuy, USA (Retired).
7. Inserting the Human Factors Into Combat Models: James Dunnigan.
8. An Overview of Human Performance Models and Potential Applications to Combat Simulation: Grant R. McMillan and Edward A. Martin.
9. R. Laughery and V. Gawron, "Making SAINT Models More Representative of Human Behavior: The Theory and Application of the MOPADS Skill Moderator Function Subroutine, Report No. 5.6, Army Research Institute Field Unit–Fort Bliss, Texas, March 1984.
10. S. VanNostrand, "Model Effectiveness as a Function of Personnel", Study Report CAA–SR–86–34 (ADB109139L), U.S. Army Concepts analysis Agency, September 1986.
11. A. Newell and H. Simon, "Human Problem Solving", McGraw–Hill, 1972.

Note: Because the reference list for Chapter III is so extensive it is provided in that chapter following the Working Group 2 report.

Appendix C
LIST OF ACRONYMS AND THEIR DEFINITIONS

AIAA	– American Institute of Aeronautics and Astronautics
ANSI	– American National Standards Institute
ARTBASS	– Army Training Battle Simulator System (Army Combined Arms Command–Training)
AURA	– Army Unit Resiliency Analysis Model (Ballistics Research Laboratory)
CASTFOREM	– Combat Arms Task Force Engagement Model (TRADOC Analysis Command)
CEM	– Concepts Evaluation Model (U.S. Army Concepts Analysis Agency)
CORBAN	– Corps Battle Analyzer (TRADOC)
CSERIAC	– Crew Systems Ergonomic Research and Information Analysis Center, WPAFB, Ohio
DNA	– Defense Nuclear Agency
FORCEM	– Force Evaluation Model (U.S. Army Concepts Analysis Agency)
FS	– Fellow of the Society (MORS)
JANUS	– A series of land combat models with some limited air and naval operations. Primarily sponsored by Laurence Livermore National Laboratory and US Army TRADOC
JESS	– Corps level (Combined Arms Army) model
JTLS	– Joint Theater Level Simulation (US Air Force Joint Warfare Center)
KORA	– Corps level wargame model sponsored by W. German Ministry of Defense (see MORIMOC II Proceedings, Pages 350–398)
MOPP	– Mission Oriented Protective Posture
MORIMOC	– More Operational Realism in Modeling of Combat
MICRO–SAINT	– Task network simulation language
RSAS	– Rand Strategy Assessment System (see MORIMOC II Proceedings, Pages 774–791) (Office of Secretary of Defense)
SIMNET	– Simulator Network (DARPA project)
SIMTECH 97	– MORS Workshop on Simulation Technology 1997
TPDC	– Training and Personnel Data Center
TRADOC	– U.S. Army Training and Doctrine Command
VECTOR	– Theater Level Land War Campaign Models Developed by Vector Research, Inc.
VIC	– Vector In Commander Model (TRADOC Analysis Center – White Sands Missile Range)

Appendix D
HIERARCHY OF HUMAN FACTORS

The hierarchy of human factors is presented in two forms: levels one through four in flowchart form in Appendix D–1 (Figures D–1 through D–22) and the complete hierarchy in text form in Appendix D–2, Table D–1.

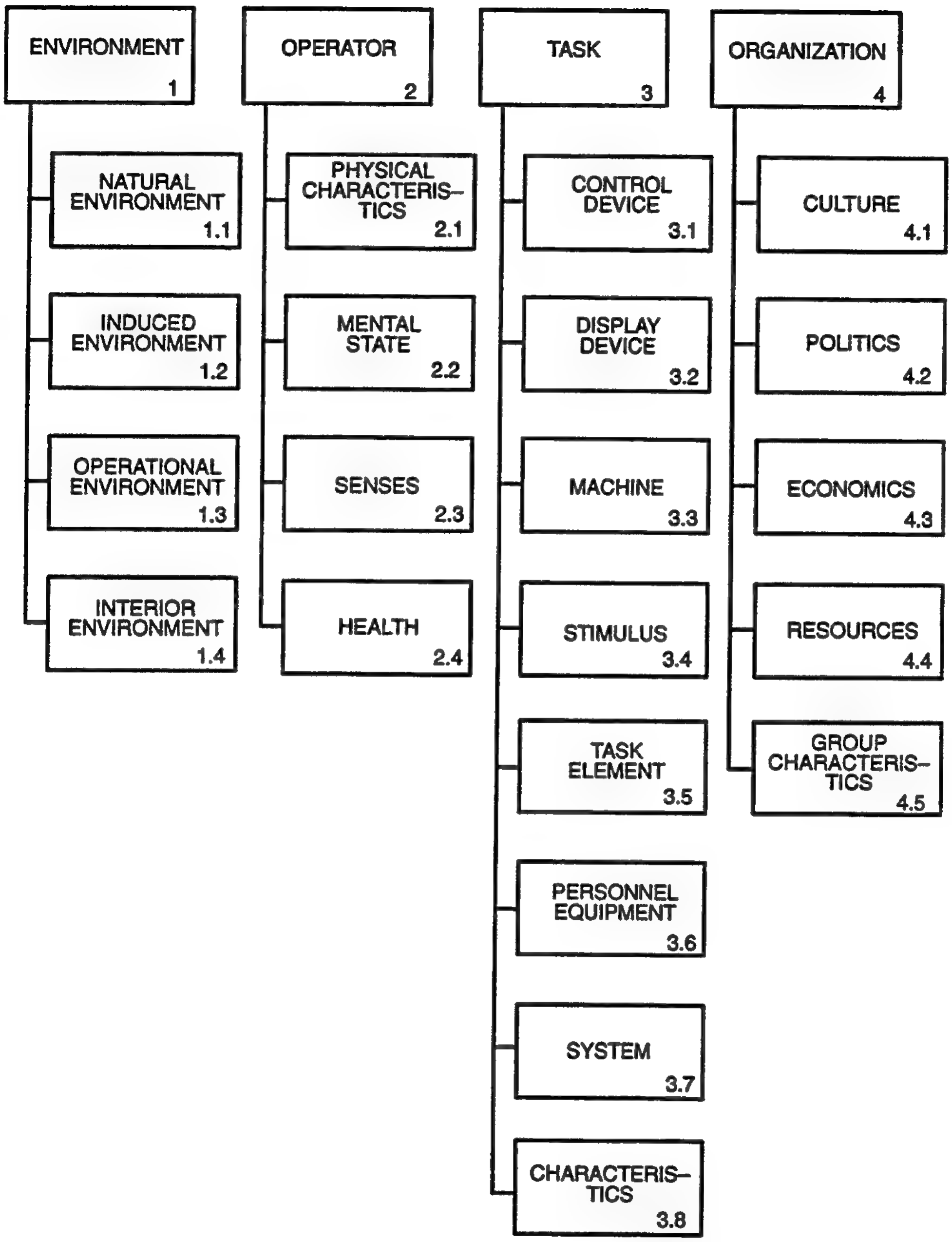

Figure D–1 LEVELS ONE AND TWO OF HIERARCHY OF HUMAN FACTORS

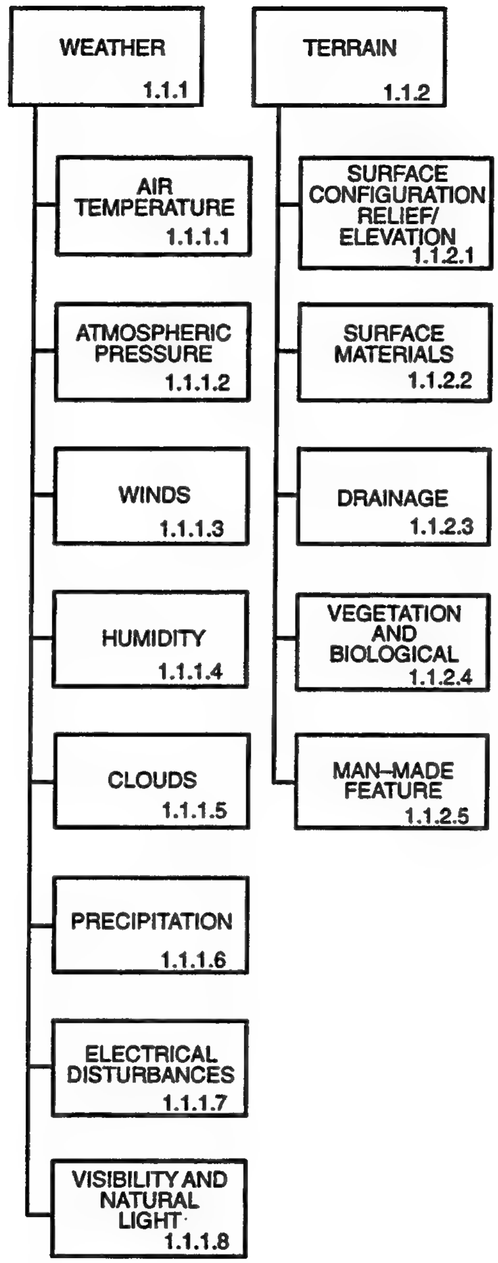

Figure D–2 LEVELS THREE AND FOUR OF HIERARCHY OF HUMAN FACTORS, NATURAL ENVIRONMENT

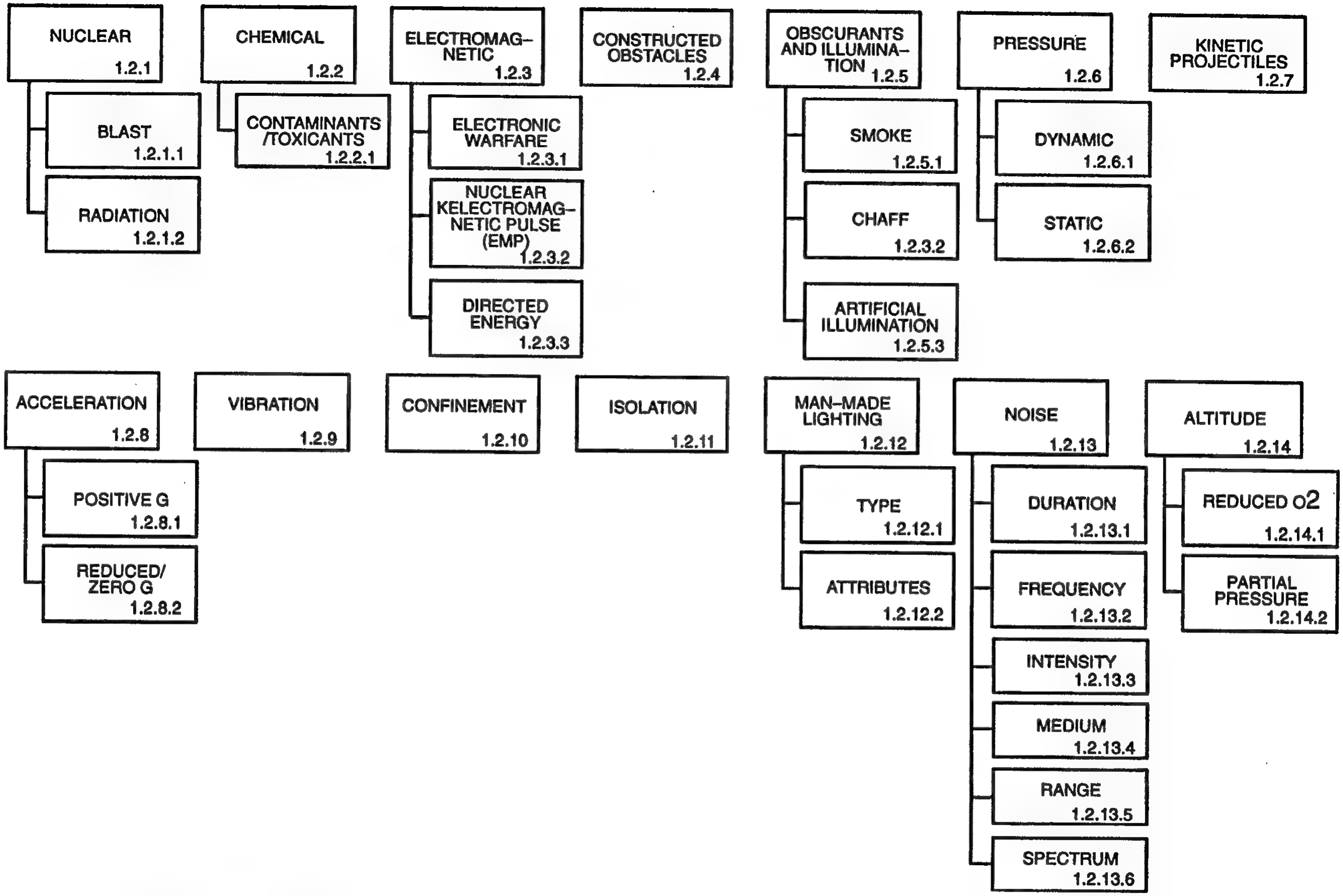

Figure D–3 LEVELS THREE AND FOUR OF HIERARCHY OF HUMAN FACTORS, INDUCED ENVIRONMENT

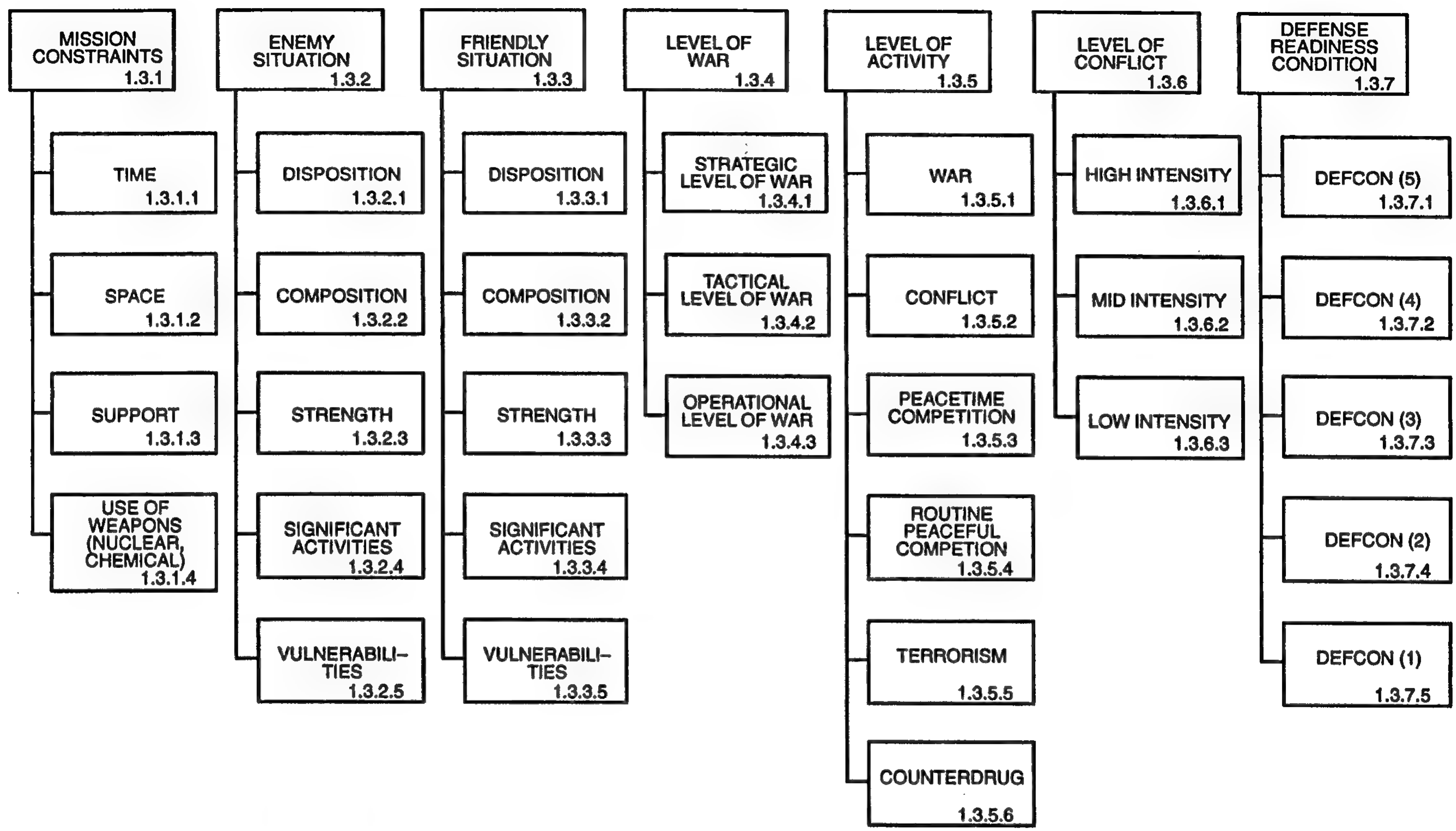

Figure D–4 LEVELS THREE AND FOUR OF HIERARCHY OF HUMAN FACTORS, OPERATIONAL ENVIRONMENT

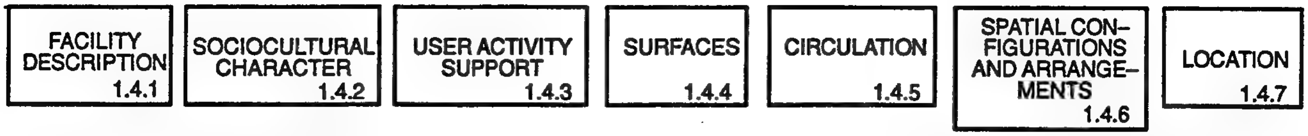

Figure D–5 LEVEL THREE OF HIERARCHY OF HUMAN FACTORS, INTERIOR ENVIRONMENT

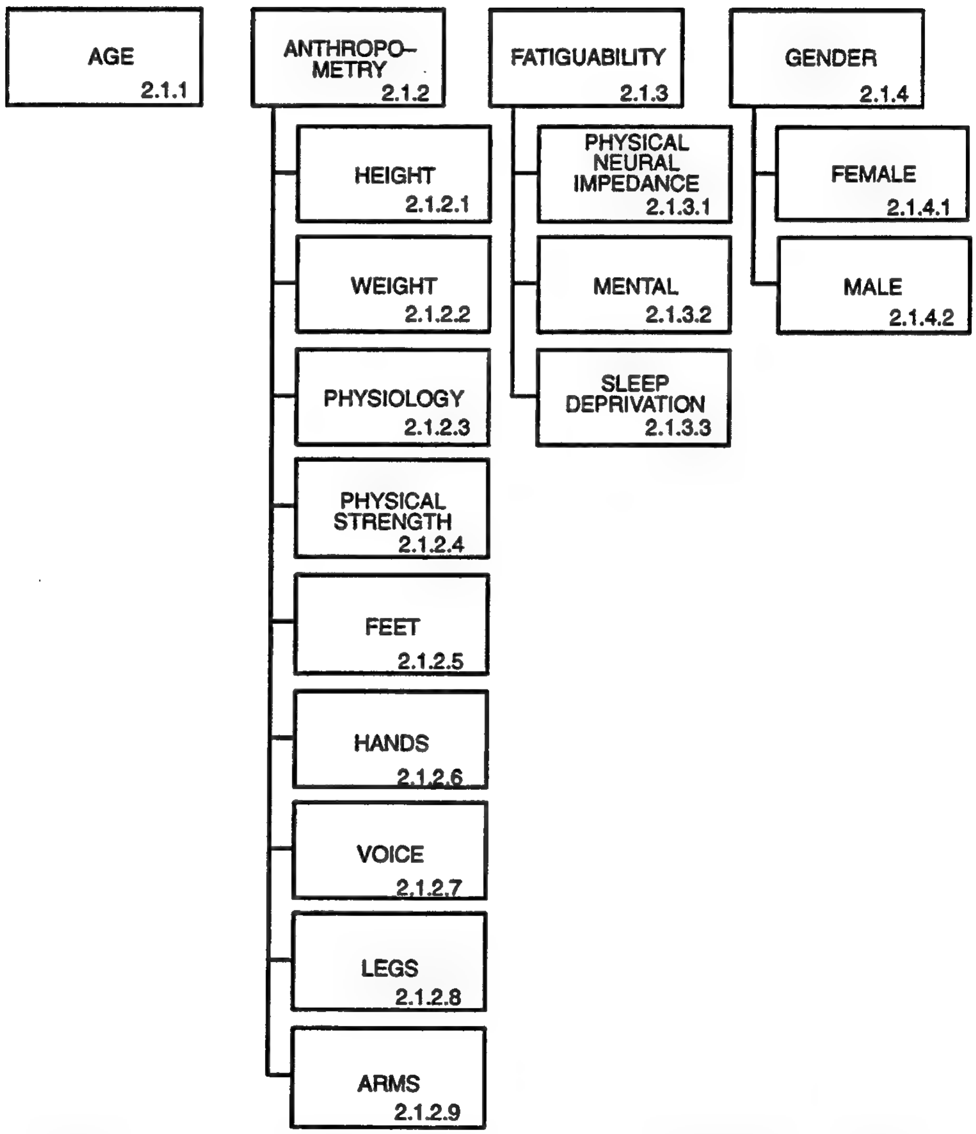

Figure D–6 LEVELS THREE AND FOUR OF HIERARCHY OF HUMAN FACTORS, PHYSICAL CHARACTERISTICS

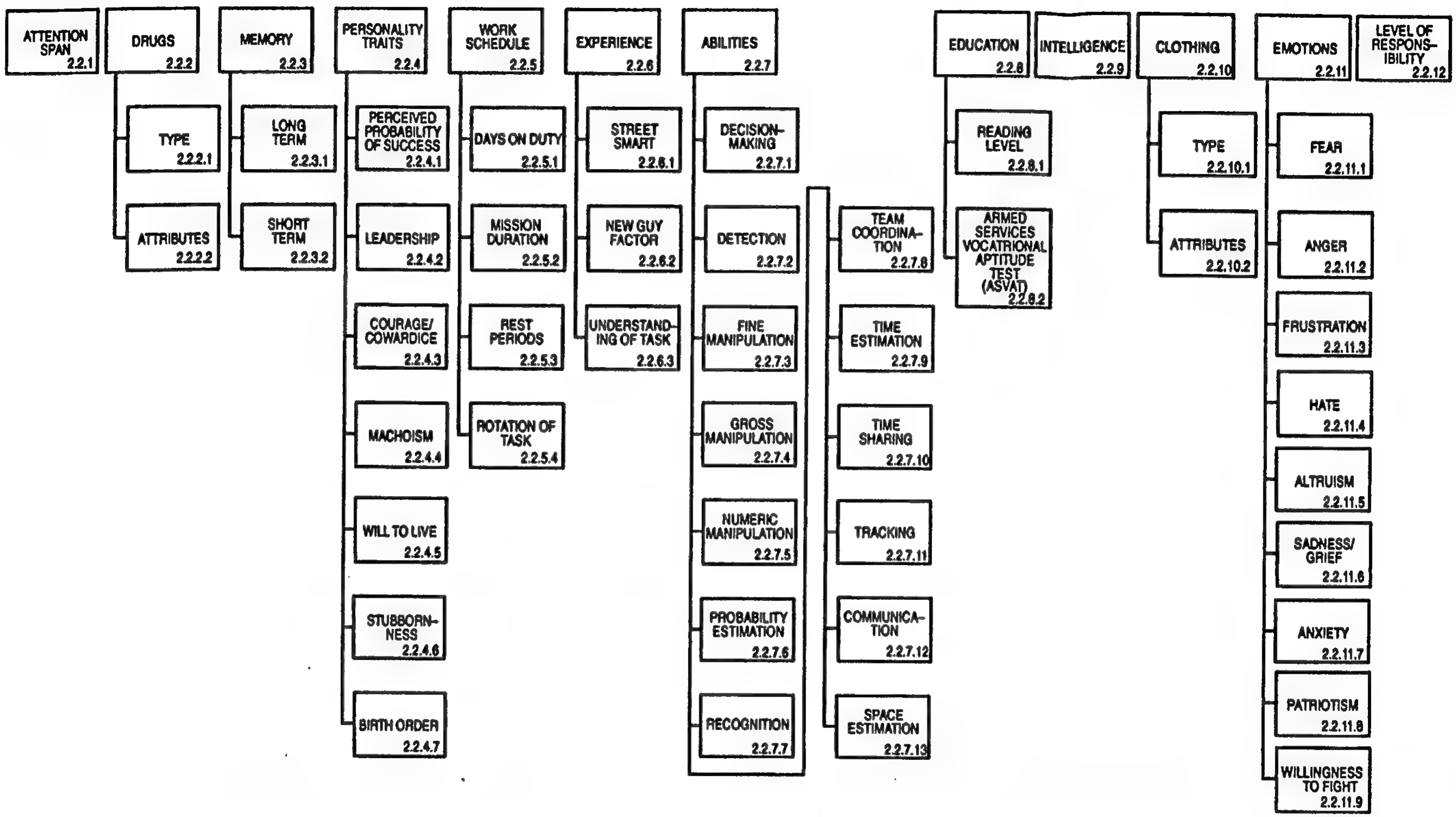

Figure D–7 LEVELS THREE AND FOUR OF HIERARCHY OF HUMAN FACTORS, MENTAL STATE

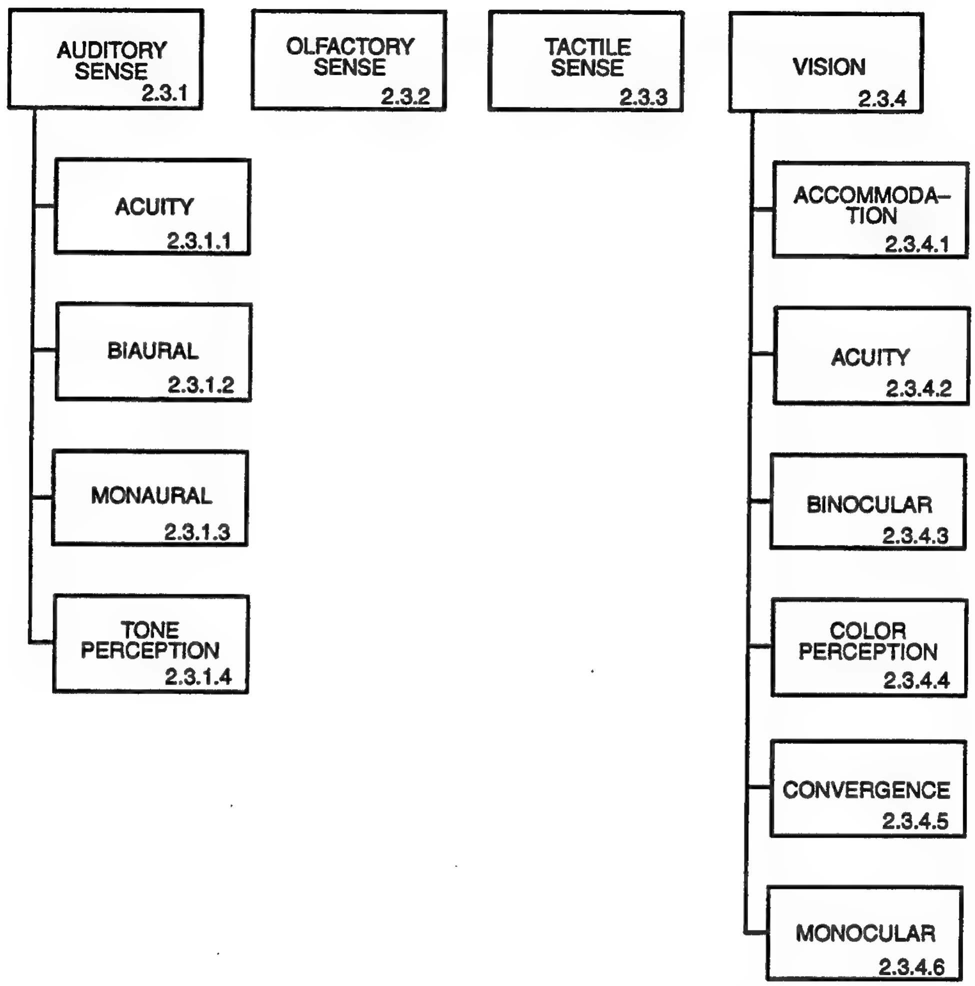

Figure D–8 LEVELS THREE AND FOUR OF HIERARCHY OF HUMAN FACTORS, SENSES

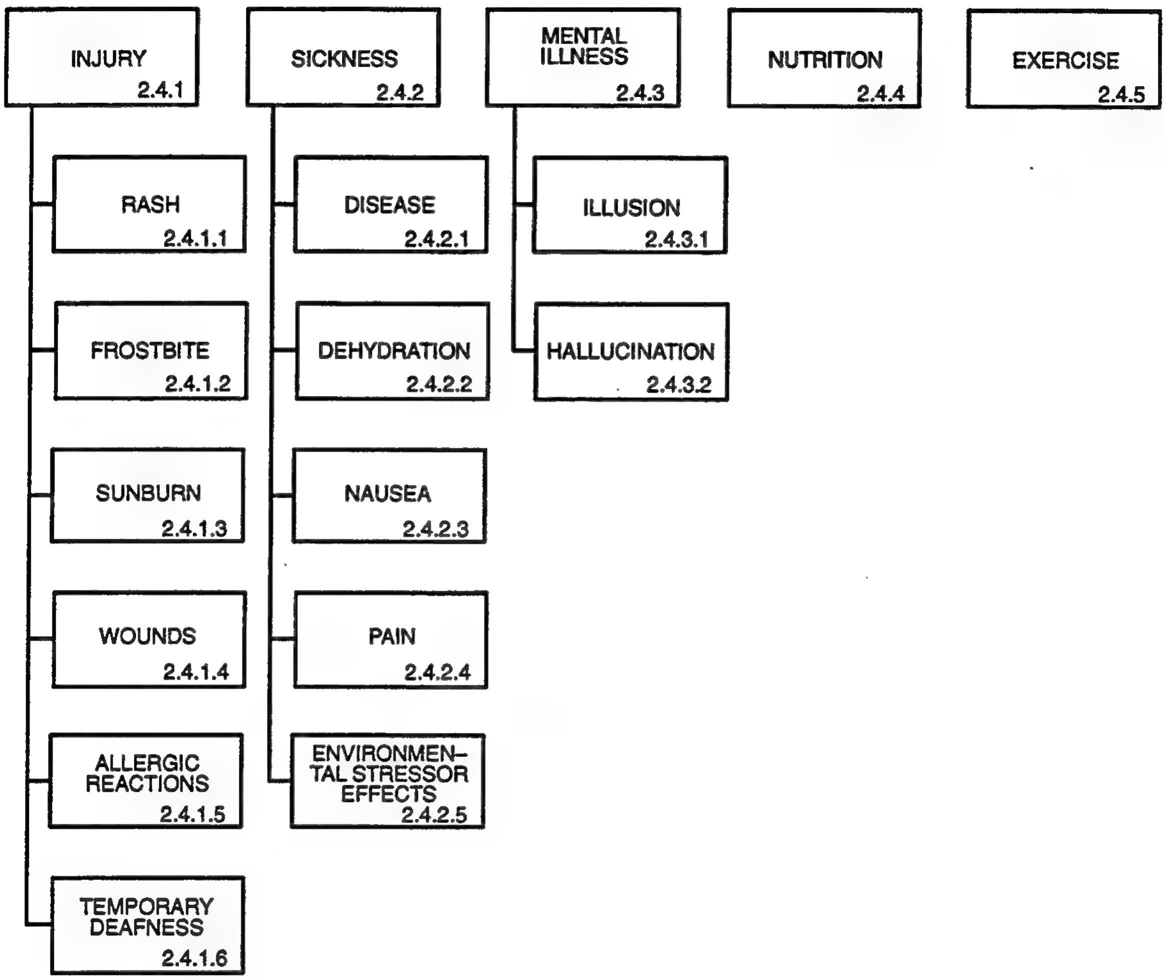

Figure D–9 LEVELS THREE AND FOUR OF HIERARCHY OF HUMAN FACTORS, HEALTH

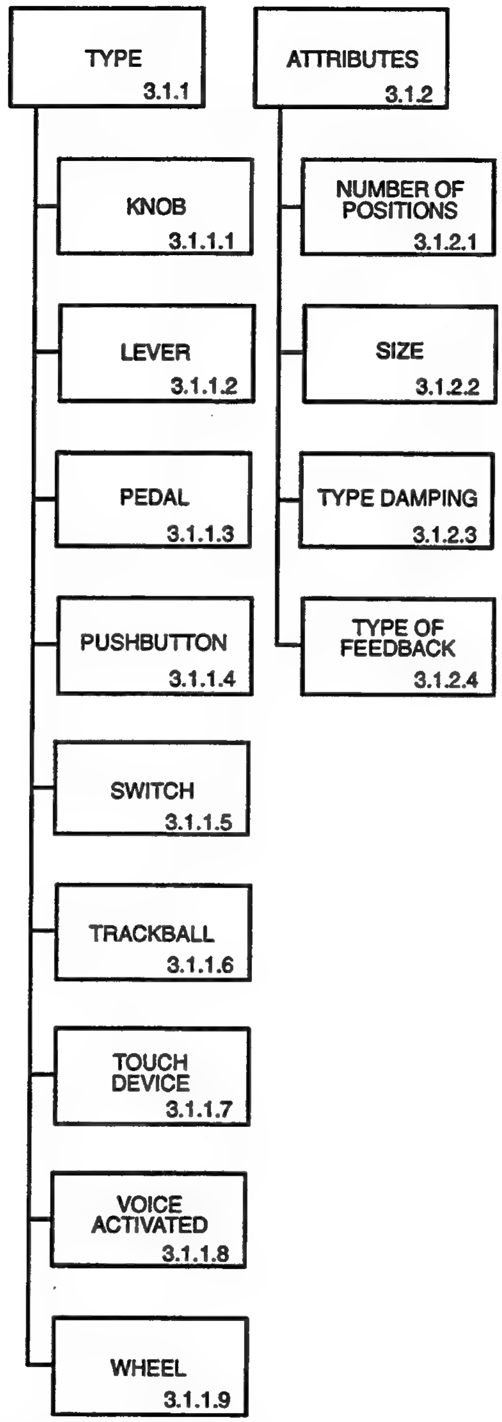

Figure D–10 LEVELS THREE AND FOUR OF HIERARCHY OF HUMAN FACTORS, CONTROL DEVICE

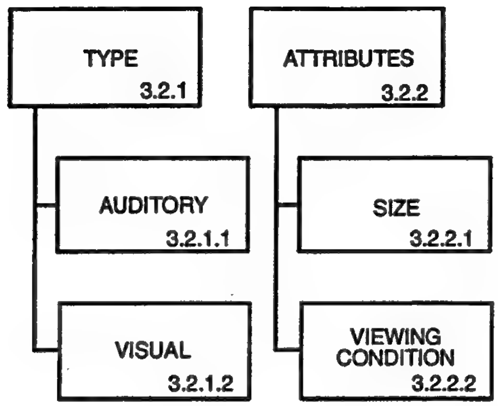

Figure D–11 **LEVELS THREE AND FOUR OF HIERARCHY OF HUMAN FACTORS, DISPLAY DEVICE**

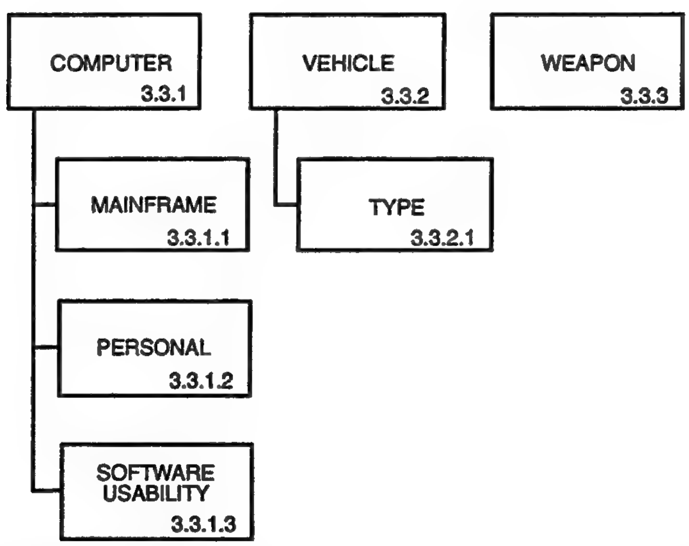

Figure D–12 **LEVELS THREE AND FOUR OF HIERARCHY OF HUMAN FACTORS, MACHINE**

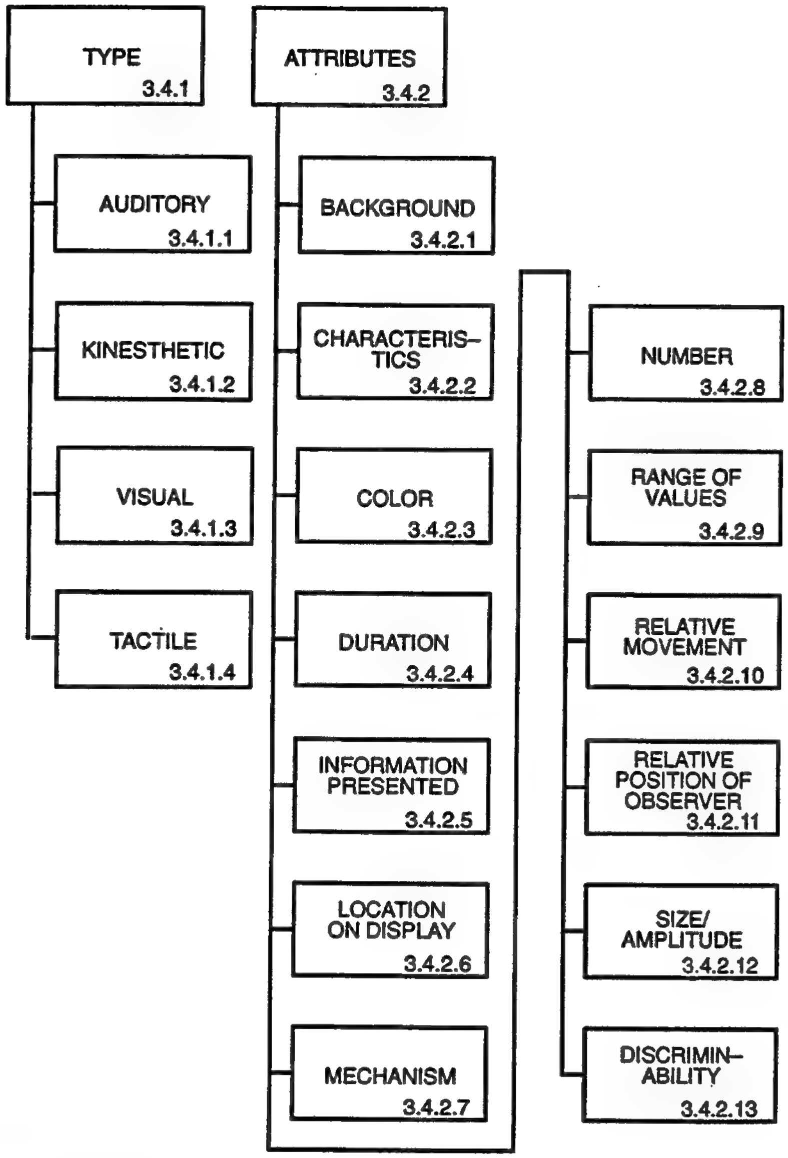

Figure D–13 LEVELS THREE AND FOUR OF HIERARCHY OF HUMAN FACTORS, STIMULUS

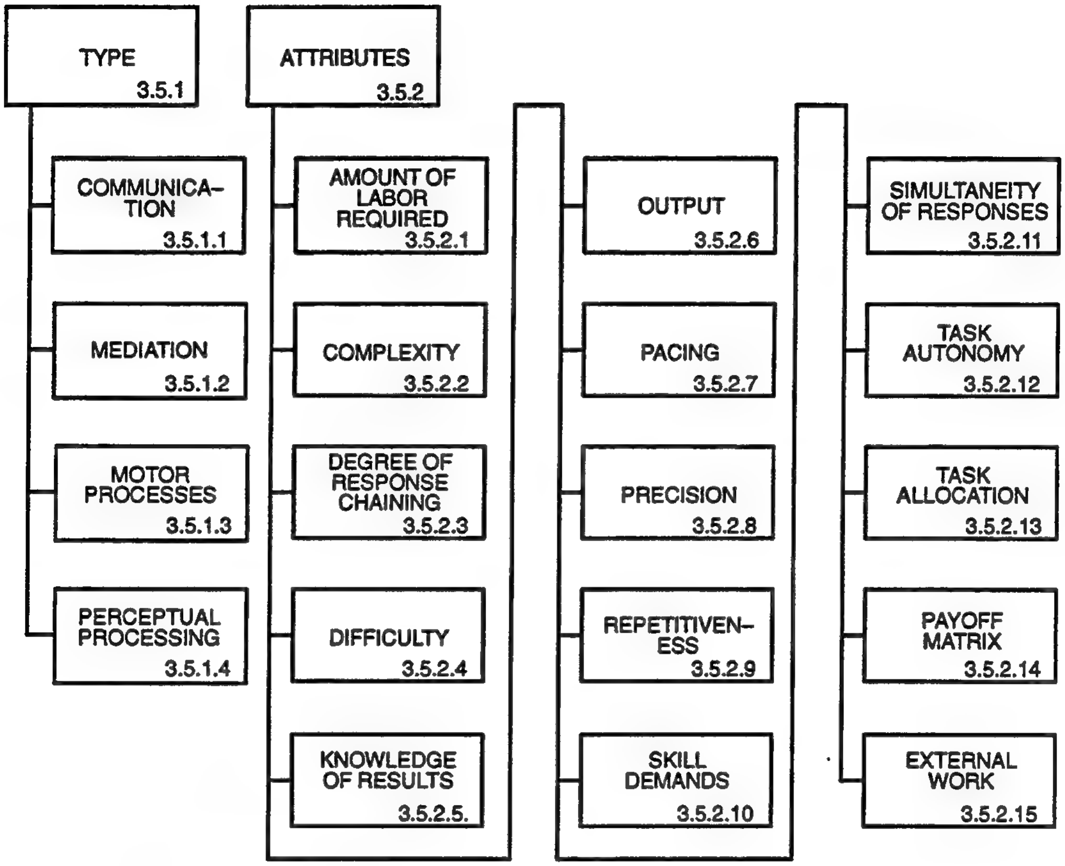

Figure D–14 LEVELS THREE AND FOUR OF HIERARCHY OF HUMAN FACTORS, TASK ELEMENT

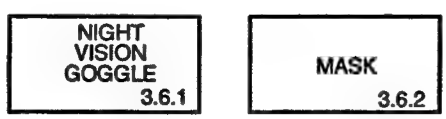

Figure D–15 LEVEL THREE OF HIERARCHY OF HUMAN FACTORS, PERSONAL EQUIPMENT

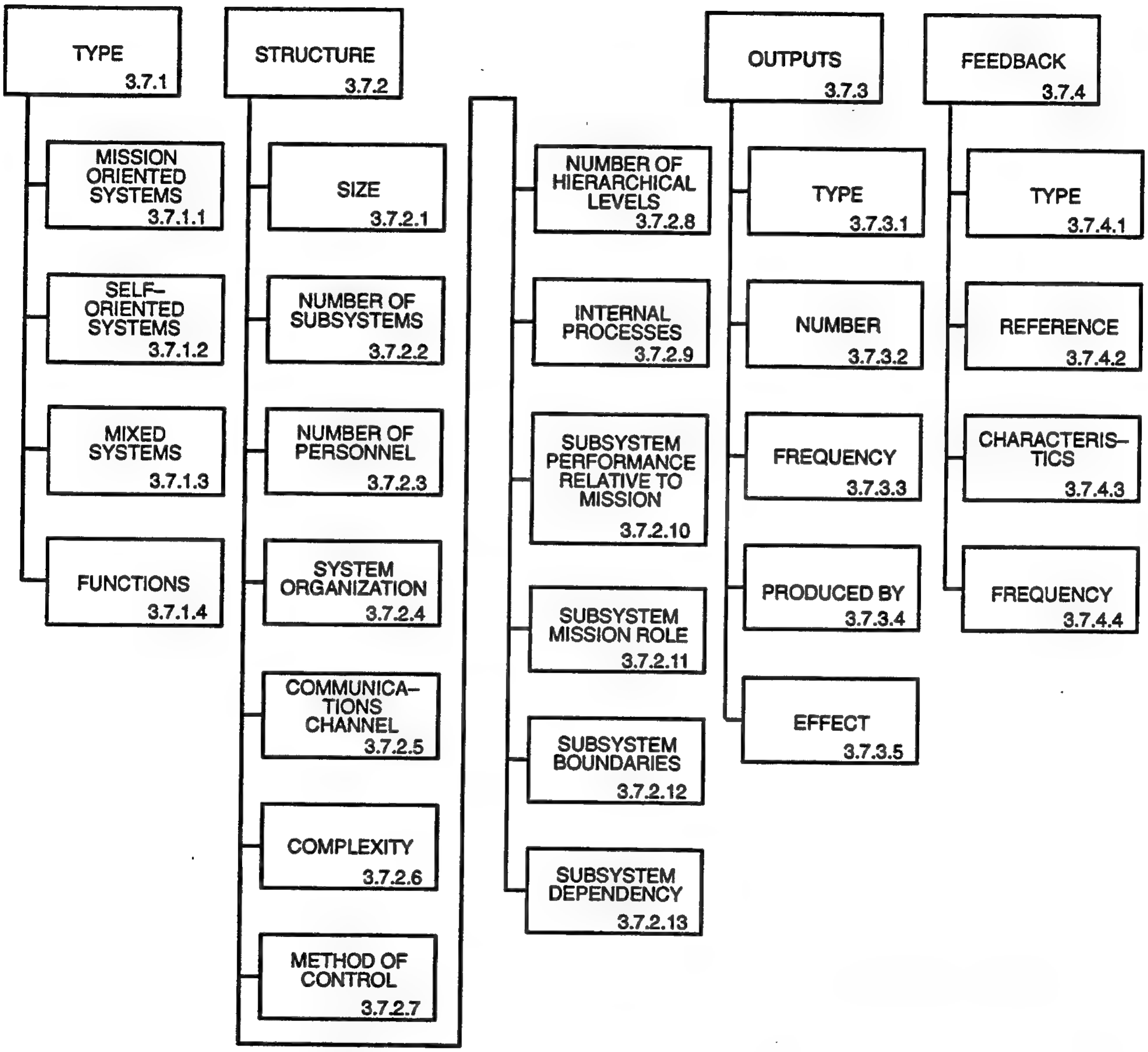

Figure D–16 LEVELS THREE AND FOUR OF HIERARCHY OF HUMAN FACTORS, SYSTEM

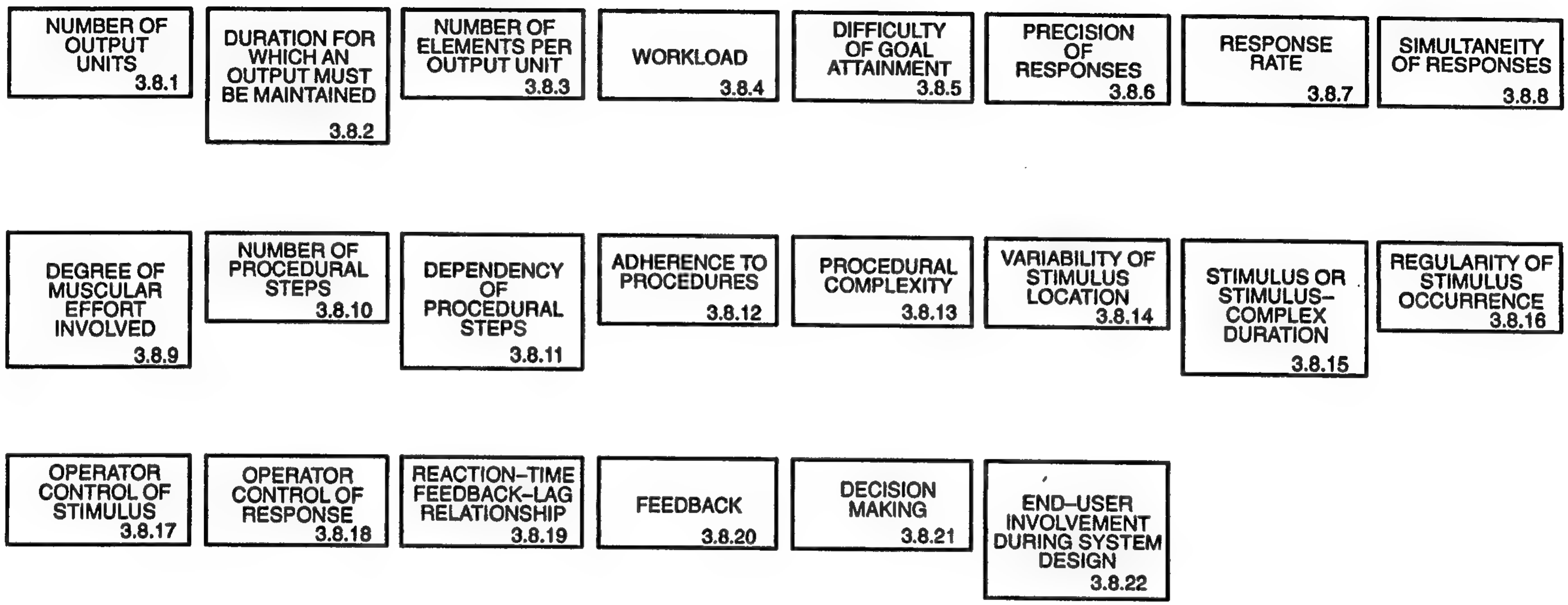

Figure D–17 LEVEL THREE OF HIERARCHY OF HUMAN FACTORS, CHARACTERISTICS

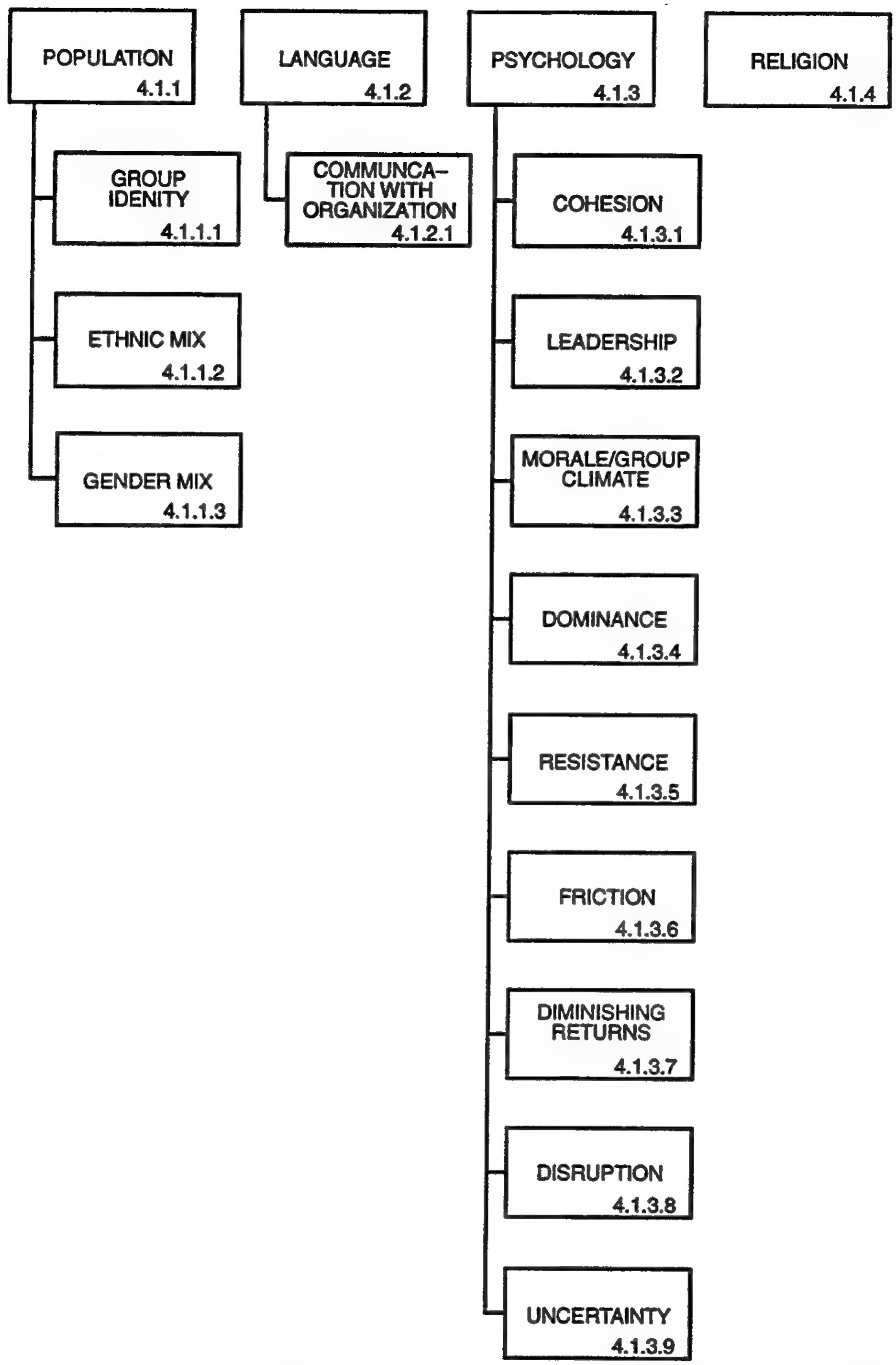

Figure D–18 LEVELS THREE AND FOUR OF HIERARCHY OF HUMAN FACTORS, CULTURE

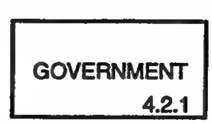

Figure D–19 LEVEL THREE OF HIERARCHY OF HUMAN FACTORS, POLITICS

Figure D–20 LEVEL THREE OF HIERARCHY OF HUMAN FACTORS, ECONOMICS

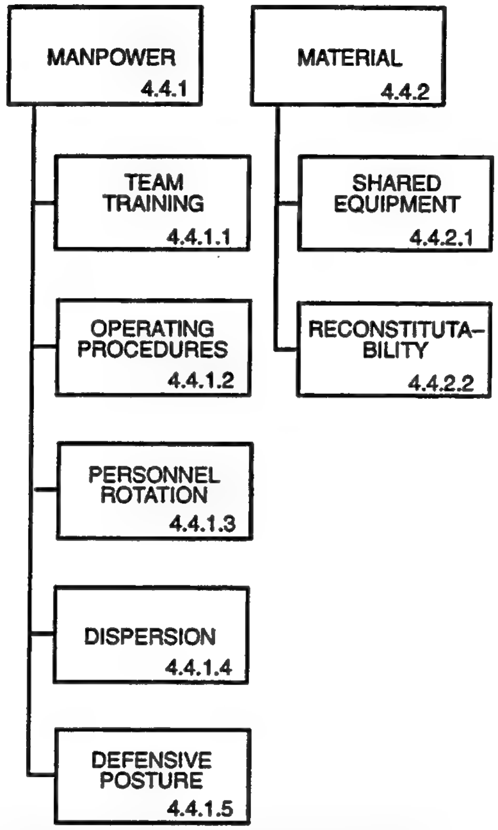

Figure D–21 LEVELS THREE AND FOUR OF HIERARCHY OF HUMAN FACTORS, RESOURCES

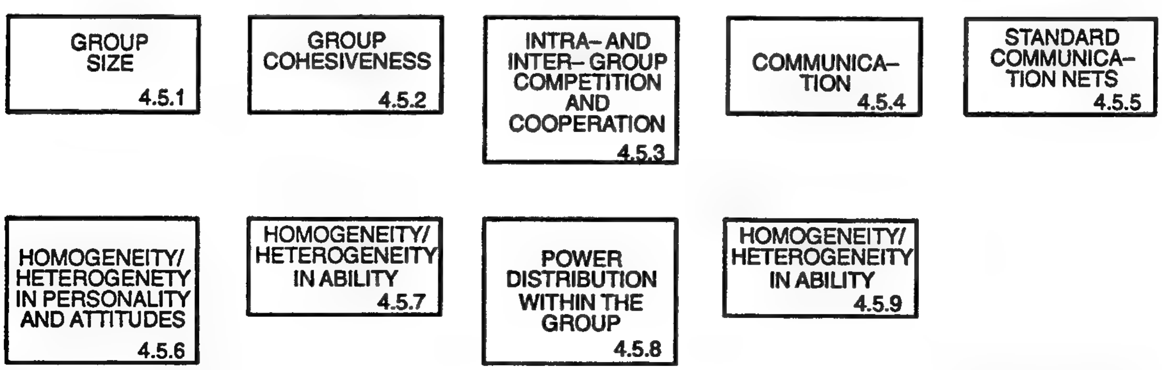

Figure D–22 LEVEL THREE OF HIERARCHY OF HUMAN FACTORS, GROUP CHARACTERISTICS

Table D–1
HIERARCHY OF HUMAN FACTORS

Level	Name	Unit	Data Source
1	**Environment**		CSERIAC
1.1	***Natural Environment***		CSERIAC
1.1.1	Weather		CSERIAC
1.1.1.1	Air Temperature	degrees Kelvin	Army Research Institute of Environmental Medicine (ARIEM); Dr. Roger Glaser
1.1.1.1.1	Range	degrees Kelvin	ARIEM
1.1.1.1.2	Variability	degrees Kelvin	ARIEM
1.1.1.1.3	Extremes	degrees Kelvin	ARIEM
1.1.1.1.4	Duration	seconds	ARIEM
1.1.1.1.5	Altitude Above Ground	meters	ARIEM
1.1.1.2	Atmospheric Pressure	mmHg	ARIEM
1.1.1.2.1	Vapor Pressure of Air Saturated Water	mmHg	ARIEM
1.1.1.3	Winds		CSERIAC
1.1.1.3.1	Direction	degrees	CSERIAC
1.1.1.3.2	Speed	meters per second	CSERIAC
1.1.1.3.3	Turbulence	meters per second	CSERIAC
1.1.1.4	Humidity	percent	ARIEM
1.1.1.5	Clouds		ARIEM
1.1.1.5.1	Type		ARIEM
1.1.1.5.2	Height (base to top)		ARIEM
1.1.1.5.3	Coverage (clear, scattered, broken, overcast)		
1.1.1.6	Precipitation	centimeters	Aeronautical Systems Division (ASD) Staff Meteorologist
1.1.1.6.1	Type (visible moisture)		ASD Staff Meteorologist
1.1.1.6.1.1	Hail	centimeters	ASD Staff Meteorologist
1.1.1.6.1.2	Rain	centimeters	ASD Staff Meteorologist
1.1.1.6.1.3	Sleet	centimeters	ASD Staff Meteorologist
1.1.1.6.1.4	Snow	centimeters	ASD Staff Meteorologist
1.1.1.6.1.4.1	Soft Snow	centimeters of snow print left by foot	ARIEM
1.1.1.6.1.4.2	Hard–Packed Snow	centimeters of snow print left by foot	ARIEM
1.1.1.6.1.5	Ice	centimeters	CSERIAC
1.1.1.6.2	Duration (continuous, intermittent, shower)	seconds	ASD Staff Meteorologist
1.1.1.6.3	Intensity (fall rate, visibility reduction)	centimeters per minute	ASD Staff Meteorologist
1.1.1.7	Electrical Disturbances		ASD Staff Meteorologist
1.1.1.7.1	Lightning		ASD Staff Meteorologist
1.1.1.7.2	Solar Storms		ASD Staff Meteorologist

1.1.1.8	Visibility and Natural Light	lux	CSERIAC; Lees, Kimbal, and Hofmann (1976)
1.1.1.8.1	Smoke	ppm	CSERIAC
1.1.1.8.2	Dust	ppm	CSERIAC
1.1.1.8.3	Fog	ppm	CSERIAC
1.1.1.8.4	Haze	ppm	CSERIAC
1.1.1.8.5	Illumination	lux	CSERIAC
1.1.1.8.5.1	Twilights Beginning/Ending	minutes	AMC Night Vision Laboratory (NVL); Naval Health Research Center
1.1.1.8.5.2	Moon Phase/Rise/Set	minutes	AMC NVL
1.1.1.8.5.3	Star Brilliance	lux	AMC NVL
1.1.1.8.5.4	Sunlight	lux	AMC NVL
1.1.2	Terrain		Army Field Manual (AFM) 100–5; Defense Mapping Agency (DMA); TRAC (1966)
1.1.2.1	Surface Configuration (Relief/Elevation)		AFM 100–5; DMA; TRAC (1966)
1.1.2.1.1	Minor Relief Features		AFM 100–5; DMA; TRAC (1966)
1.1.2.1.1.1	High ground (mesas, buttes, ridges, dunes)		AFM 100–5; DMA; TRAC (1966)
1.1.2.1.1.2	Depressions (basins, canyons, wadis)		AFM 100–5; DMA; TRAC (1966)
1.1.2.1.1.3	Breaks in High ground (passes, gaps)		AFM 100–5; DMA; TRAC (1966)
1.1.2.1.1.4	Special features (talus slopes, boulder fields)		AFM 100–5; DMA; TRAC (1966)
1.1.2.1.2	Microrelief Features (low escarpments, stream banks, pits, dikes, swales, kames, moraines)		AFM 100–5; DMA; TRAC (1966)
1.1.2.1.3	Elevation/Slope		AFM 100–5; DMA; TRAC (1966)
1.1.2.1.3.1	Shape (convex, concave, uniform)		AFM 100–5; DMA; TRAC (1966)
1.1.2.1.3.2	Angle (percent, degrees, gradient)		AFM 100–5; DMA; TRAC (1966)
1.1.2.2	Surface Materials		ARIEM
1.1.2.2.1	Soil		ARIEM
1.1.2.2.1.1	Composition (gravel, silt, sand, clay)		ARIEM
1.1.2.2.1.2	Depth		ARIEM
1.1.2.2.1.3	Moisture		ARIEM
1.1.2.2.1.4	Layering		ARIEM
1.1.2.2.2	Rock		ARIEM
1.1.2.2.2.1	Formation Class (igneous, sedimentary, metamorphic)		ARIEM
1.1.2.2.2.2	Thickness		ARIEM
1.1.2.2.3	Trafficability		ARIEM
1.1.2.3	Drainage		ARIEM
1.1.2.3.1	Watersheds, Water Courses, and Water bodies (stream, river, creek, canal, lake)		ARIEM

1.1.2.3.1.1	Flow Velocity, Tidal Effects, Flooding Potential	ARIEM
1.1.2.3.1.2	Crossings	ARIEM
1.1.2.3.1.3	Banks/Shore (composition, height, condition)	ARIEM
1.1.2.3.1.4	Adjacent Terrain	ARIEM
1.1.2.3.1.5	Dimension (width, depth)	ARIEM
1.1.2.3.2	Wet Areas (swamp, marsh, bog, paddy)	ARIEM
1.1.2.3.2.1	Inundation Causes	ARIEM
1.1.2.3.2.2	Crossings	ARIEM
1.1.2.3.2.3	Flooding Potential	ARIEM
1.1.2.4	Vegetation and Biological	American Association of Botanical Gardens and Arboreta; American Society for Horticultural Science; Botanical Society of America; Brooklyn Botanic Garden Library; National Arboretum Library; National Herbarium and Botanic Garden Library; New York Botanical Garden Library
1.1.2.4.1	Trees	American Association of Botanical Gardens and Arboreta; American Society for Horticultural Science; Botanical Society of America; Brooklyn Botanic Garden Library; National Arboretum Library; National Herbarium and Botanic Garden Library; New York Botanical Garden Library
1.1.2.4.1.1	Canopy Height and Closure	American Association of Botanical Gardens and Arboreta; American Society for Horticultural Science; Botanical Society of America; Brooklyn Botanic Garden Library; National Arboretum Library; National Herbarium and Botanic Garden Library; New York Botanical Garden Library
1.1.2.4.1.2	Density and Trunk Diameter	American Association of Botanical Gardens and Arboreta; American Society for Horticultural Science; Botanical Society of America; Brooklyn Botanic Garden Library; National Arboretum Library; National Herbarium and Botanic Garden Library; New York Botanical Garden Library
1.1.2.4.2	Shrubs (hedgerows)	ARIEM
1.1.2.4.3	Grasses and crops	ARIEM
1.1.2.4.4	Micro–organisms	CBIAC
1.1.2.4.4.1	Biological Agents	CBIAC
1.1.2.4.4.1.1	Bacterial Agents	CBIAC
1.1.2.4.4.1.1.1	Bacillus Anthracis	CBIAC
1.1.2.4.4.1.1.2	Bacillus Brucella	CBIAC
1.1.2.4.4.1.1.2.1	Brucella Abortus	CBIAC
1.1.2.4.4.1.1.2.2	Brucella Canis	CBIAC
1.1.2.4.4.1.1.2.3	Brucella Melitensis	CBIAC
1.1.2.4.4.1.1.2.4	Brucella Neotamal	CBIAC
1.1.2.4.4.1.1.2.5	Brucella Ovis	CBIAC
1.1.2.4.4.1.1.2.6	Brucella SSP	CBIAC

1.1.2.4.4.1.1.2.7	Brucella Suls	CBIAC
1.1.2.4.4.1.1.3	Bacillus Cereus	CBIAC
1.1.2.4.4.1.1.4	Bacillus Stearothermophillus	CBIAC
1.1.2.4.4.1.1.5	Francisella Tularensis	CBIAC
1.1.2.4.4.1.1.6	Macaca Mulaita	CBIAC
1.1.2.4.4.1.1.7	Malleomyces Mallei	CBIAC
1.1.2.4.4.1.1.8	Malleomyces Pseudomallei	CBIAC
1.1.2.4.4.1.1.9	Myobacterium Tuberculosis	CBIAC
1.1.2.4.4.1.1.10	Pasteurella Pestis	CBIAC
1.1.2.4.4.1.1.11	Pasteurella Tularensis	CBIAC
1.1.2.4.4.1.1.12	Salmonella SPP	CBIAC
1.1.2.4.4.1.1.13	Salmonella Typhimurium	CBIAC
1.1.2.4.4.1.1.14	Serratia Marcescens	CBIAC
1.1.2.4.4.1.1.15	Spores	CBIAC
1.1.2.4.4.1.1.16	Tularensis	CBIAC
1.1.2.4.4.1.1.17	Vibrio Cholerae	CBIAC
1.1.2.4.4.1.1.18	Yersinia Pestis	CBIAC
1.1.2.4.4.1.2	Fungi	CBIAC
1.1.2.4.4.1.2.1	Coccidiodes Immitis	CBIAC
1.1.2.4.4.1.2.2	Herbicidal Fungi	CBIAC
1.1.2.4.4.1.2.2.1	Helminthosporium Oryzae	CBIAC
1.1.2.4.4.1.2.2.2	Phytophtera Infestans	CBIAC
1.1.2.4.4.1.2.2.3	Piricularia Oryzae	CBIAC
1.1.2.4.4.1.2.2.4	Sclerotium Rolfsil	CBIAC
1.1.2.4.4.1.2.3	Histopolasma Capsulatum	CBIAC
1.1.2.4.4.1.3	Rickettsia	CBIAC
1.1.2.4.4.1.3.1	Coxiella Burnetti	CBIAC
1.1.2.4.4.1.3.2	Rickettsia Australis	CBIAC
1.1.2.4.4.1.3.3	Rickettsia Conorii	CBIAC
1.1.2.4.4.1.3.4	Ricettsia Mooseri	CBIAC
1.1.2.4.4.1.3.5	Rickettsia Prowazekii	CBIAC
1.1.2.4.4.1.3.6	Rickettsia Rickettsii	CBIAC
1.1.2.4.4.1.3.7	Rickettsia Siberica	CBIAC
1.1.2.4.4.1.3.8	Rickettsia Tsutsugamuski	CBIAC
1.1.2.4.4.1.4	Toxins	CBIAC
1.1.2.4.4.1.4.1	Aflatoxin G2	CBIAC
1.1.2.4.4.1.4.2	Batrachotoxin	CBIAC
1.1.2.4.4.1.4.3	Black Widow Spider Venom	CBIAC
1.1.2.4.4.1.4.4	Botulinum	CBIAC
1.1.2.4.4.1.4.4.1	Botulinum Neurotoxin A	CBIAC
1.1.2.4.4.1.4.4.2	Botulinum Neurotoxin B	CBIAC
1.1.2.4.4.1.4.4.3	Batolinum Neurotoxin C1	CBIAC
1.1.2.4.4.1.4.4.4	Batolinum Neurotoxin C2	CBIAC
1.1.2.4.4.1.4.4.5	Botulinum Neurotoxin D	CBIAC
1.1.2.4.4.1.4.4.6	Botulinum Neurotoxin E	CBIAC
1.1.2.4.4.1.4.4.7	Botulinum Neurotoxin F	CBIAC

1.1.2.4.4.1.4.4.8	Botulinum Neurotoxin G	CBIAC
1.1.2.4.4.1.4.5	Clostridium Botulinum	CBIAC
1.1.2.4.4.1.4.6	Cobra Venom	CBIAC
1.1.2.4.4.1.4.7	Debromoplysiatoxin	CBIAC
1.1.2.4.4.1.4.8	Deoxynivalenol	CBIAC
1.1.2.4.4.1.4.9	Diacetoxyscirpenol	CBIAC
1.1.2.4.4.1.4.10	Endotoxins	CBIAC
1.1.2.4.4.1.4.11	Fusarium Trichothecenes	CBIAC
1.1.2.4.4.1.4.12	Hornet Venom	CBIAC
1.1.2.4.4.1.4.13	HT–2	CBIAC
1.1.2.4.4.1.4.14	Mandarotoxin	CBIAC
1.1.2.4.4.1.4.15	Microcystin	CBIAC
1.1.2.4.4.1.4.16	Orientotoxin	CBIAC
1.1.2.4.4.1.4.17	Palytoxin	CBIAC
1.1.2.4.4.1.4.18	Picrotoxin	CBIAC
1.1.2.4.4.1.4.19	Rattlesnake Venom	CBIAC
1.1.2.4.4.1.4.20	Ricin	CBIAC
1.1.2.4.4.1.4.21	Saxitoxin	CBIAC
1.1.2.4.4.1.4.22	Scorpion Venom	CBIAC
1.1.2.4.4.1.4.23	Snake Venom	CBIAC
1.1.2.4.4.1.4.24	Staphylococcal Enterotoxin	CBIAC
1.1.2.4.4.1.4.24.1	Staphylococcal Enterotoxin A	CBIAC
1.1.2.4.4.1.4.24.2	Stophylococcal Enterotoxin B	CBIAC
1.1.2.4.4.1.4.25	Tetrodotoxin	CBIAC
1.1.2.4.4.1.4.26	Trichothecenes	CBIAC
1.1.2.4.4.1.4.26.1	Nivalenol	CBIAC
1.1.2.4.4.1.4.26.2	T2 Toxin	CBIAC
1.1.2.4.4.1.4.27	V Cholerae Enterotoxin	CBIAC
1.1.2.4.4.1.4.28	Wasp Venom	CBIAC
1.1.2.4.4.1.4.29	Yellow Rain	CBIAC
1.1.2.4.4.1.5	Viruses	CBIAC
1.1.2.4.4.1.5.1	Chikongunya Virus	CBIAC
1.1.2.4.4.1.5.2	Chlamydia Psittaci Virus	CBIAC
1.1.2.4.4.1.5.3	Dengue Fever Virus	CBIAC
1.1.2.4.4.1.5.4	Encephalitis Viruses	CBIAC
1.1.2.4.4.1.5.4.1	Encephalitis Lethargica Virus	CBIAC
1.1.2.4.4.1.5.4.2	Japanese Encephalitis Virus	CBIAC
1.1.2.4.4.1.5.4.3	Russian Spring–Summer Encephalitis Virus	CBIAC
1.1.2.4.4.1.5.4.4	Venezuelan Equine Encephalitis Virus	CBIAC
1.1.2.4.4.1.5.4.5	Western Encephalitis Virus	CBIAC
1.1.2.4.4.1.5.5	Encephalomyelitis Viruses	CBIAC
1.1.2.4.4.1.5.5.1	Venezuelan Equine Encephalomyelitis Virus	CBIAC
1.1.2.4.4.1.5.6	Hemmorhagic Fever Virus	CBIAC
1.1.2.4.4.1.5.6.1	Ebola Fever Virus	CBIAC

1.1.2.4.4.1.5.6.2	Lassa Fever Virus	CBIAC
1.1.2.4.4.1.5.6.3	Marburg Fever Virus	CBIAC
1.1.2.4.4.1.5.7	Influenza Virus	CBIAC
1.1.2.4.4.1.5.8	Meningitis Virus	CBIAC
1.1.2.4.4.1.5.9	Newcastle Disease Virus	CBIAC
1.1.2.4.4.1.5.10	Onyong–Nyong Virus	CBIAC
1.1.2.4.4.1.5.11	Psittacosis Virus	CBIAC
1.1.2.4.4.1.5.12	Rift Valley Fever Virus	CBIAC
1.1.2.4.4.1.5.13	Smallpox Virus	CBIAC
1.1.2.4.4.1.5.14	Vesicular Stomatitis Virus	CBIAC
1.1.2.4.4.1.5.15	Yellow Fever Virus	CBIAC
1.1.2.4.4.1.6	Yeasts	CBIAC
1.1.2.4.5	Hostile Flora	CBIAC
1.1.2.4.5.1	Poison Ivy	CBIAC
1.1.2.4.5.2	Thorns	CBIAC
1.1.2.4.5.3	Aesthetics	CBIAC
1.1.2.4.6	Hostile Fauna	American Museum of Natural History; Armed Forces Medical Intelligence Center; Army Biomedical Research and Development Laboratory; Army Medical Research Institute of Infectious Diseases; Explorers Club; Field Museum of Natural History
1.1.2.4.6.1	Ticks	American Museum of Natural History; Armed Forces Medical Intelligence Center; Army Biomedical Research and Development Laboratory; Army Medical Research Institute of Infectious Diseases; Explorers Club; Field Museum of Natural History
1.1.2.4.6.2	Fleas	American Museum of Natural History; Armed Forces Medical Intelligence Center; Army Biomedical Research and Development Laboratory; Army Medical Research Institute of Infectious Diseases; Explorers Club; Field Museum of Natural History
1.1.2.4.6.3	Mosquitoes	American Museum of Natural History; Armed Forces Medical Intelligence Center; Army Biomedical Research and Development Laboratory; Army Medical Research Institute of Infectious Diseases; Explorers Club; Field Museum of Natural History
1.1.2.5	Man–Made Features	ARIEM
1.1.2.5.1	Building and Settlement	ARIEM
1.1.2.5.1.1	Urban	ARIEM
1.1.2.5.1.2	Rural	ARIEM
1.1.2.5.1.3	Industrial (factories, mines)	ARIEM
1.1.2.5.2	Transportation Routes	ARIEM
1.1.2.5.2.1	Highways	ARIEM
1.1.2.5.2.1.1	Blacktop surface	ARIEM
1.1.2.5.2.1.2	Dirt Road	ARIEM
1.1.2.5.2.2	Railways	ARIEM

1.1.2.5.2.3	Pipelines		ARIEM
1.1.2.5.2.4	Structures and Crossings		ARIEM
1.1.2.5.2.5	Ports, Harbors, Airfields		ARIEM
1.1.2.5.3	Military Sites/Fortifications		ARIEM
1.1.2.5.4	Utility and Communication Networks		ARIEM
1.2	***Induced Environment***		CSERIAC
1.2.1	Nuclear (Initial, Residual)		Defense Nuclear Agency (DNA)
1.2.1.1	Blast Overpressure	Pa	DNA
1.2.1.1.1	Dynamic		DNA
1.2.1.1.2	Static		DNA
1.2.1.2	Radiation		DNA Human Response Program (HRP); DNA Intermediate Dose Program (IDP)
1.2.1.2.1	Ionizing Radiation	Gy	DNA HRP; DNA IDP
1.2.1.2.1.1	Gamma		DNA HRP; DNA IDP
1.2.1.2.1.2	Neutron		DNA HRP; DNA IDP
1.2.1.2.1.3	Beta		DNA HRP; DNA IDP
1.2.1.2.1.4	X–Ray		DNA HRP; DNA IDP
1.2.1.2.2	Nonionizing Radiation		DNA HRP; DNA IDP
1.2.1.2.2.1	Infrared	J/m^2	DNA HRP; DNA IDP
1.2.1.2.2.2	Visible		DNA HRP; DNA IDP
1.2.1.2.2.3	uV		DNA HRP; DNA IDP
1.2.1.2.2.4	Radio Frequency	W/m^2	DNA HRP; DNA IDP
1.2.1.2.3	Radiation Shielding		Anno and Dore (1989)
1.2.1.2.3.1	Gun		Anno and Dore (1989)
1.2.1.2.3.2	FDC		Anno and Dore (1989)
1.2.1.2.3.3	Tank		Anno and Dore (1989)
1.2.1.2.3.4	ITV–TOW vehicles		Anno and Dore (1989)
1.2.1.2.4	Thermal		DNA HRP; DNA IDP
1.2.2	Chemical		CBIAC
1.2.2.1	Contaminants/Toxicants	ppm	CBIAC
1.2.2.1.1	Chemical Agents	$mg\text{–}sec/m^3$	CBIAC
1.2.2.1.1.1	Alogens	ppm	CBIAC
1.2.2.1.1.1.1	5–Hydroxtrytamine	ppm	CBIAC
1.2.2.1.1.1.2	Acetylcholine	ppm	CBIAC
1.2.2.1.1.1.3	Histamine	ppm	CBIAC
1.2.2.1.1.2	Binary Agents	ppm	CBIAC
1.2.2.1.1.2.1	EA5774	ppm	CBIAC
1.2.2.1.1.2.2	EA5823	ppm	CBIAC
1.2.2.1.1.2.3	EA5824	ppm	CBIAC
1.2.2.1.1.2.4	EA5825	ppm	CBIAC
1.2.2.1.1.2.5	EA5826	ppm	CBIAC
1.2.2.1.1.3	Blister Agents	ppm	CBIAC
1.2.2.1.1.3.1	Blister Agent Arsenicals	ppm	CBIAC
1.2.2.1.1.3.1.1	Ethyldichloroarsine	ppm	CBIAC

1.2.2.1.1.3.1.2	Methyldicloroarsine	ppm	CBIAC
1.2.2.1.1.3.1.3	Phenyldichloroarsine	ppm	CBIAC
1.2.2.1.1.3.2	H Agents	ppm	CBIAC
1.2.2.1.1.3.2.1	H	ppm	CBIAC
1.2.2.1.1.3.2.2	HD	ppm	CBIAC
1.2.2.1.1.3.2.3	HL	ppm	CBIAC
1.2.2.1.1.3.2.4	HN–1	ppm	CBIAC
1.2.2.1.1.3.2.5	HN–2	ppm	CBIAC
1.2.2.1.1.3.2.6	HN–3	ppm	CBIAC
1.2.2.1.1.3.2.7	HS	ppm	CBIAC
1.2.2.1.1.3.2.8	HT	ppm	CBIAC
1.2.2.1.1.3.2.9	THD	ppm	CBIAC
1.2.2.1.1.3.2.10	THL	ppm	CBIAC
1.2.2.1.1.3.3	L Agents	ppm	CBIAC
1.2.2.1.1.3.3.1	L	ppm	CBIAC
1.2.2.1.1.3.3.2	TL	ppm	CBIAC
1.2.2.1.1.3.4	Phosgene Oxime	ppm	CBIAC
1.2.2.1.1.3.5	Sesquimustard	ppm	CBIAC
1.2.2.1.1.3.6	T	ppm	CBIAC
1.2.2.1.1.4	Blood Agents	ppm	CBIAC
1.2.2.1.1.4.1	Arsine	ppm	CBIAC
1.2.2.1.1.4.2	Cyanogen Chloride	ppm	CBIAC
1.2.2.1.1.4.3	Hydrogen Cyanide	ppm	CBIAC
1.2.2.1.1.5	Chemical Agent Precursors	ppm	CBIAC
1.2.2.1.1.5.1	Amine Experiments	ppm	CBIAC
1.2.2.1.1.5.2	Methylphosphonic Dichloride	ppm	CBIAC
1.2.2.1.1.5.3	Methylphosphonic Difluoride	ppm	CBIAC
1.2.2.1.1.5.4	Phosphorus Oxychloride	ppm	CBIAC
1.2.2.1.1.5.5	Picrate Experiments	ppm	CBIAC
1.2.2.1.1.5.6	Pinacolyl Alcohol	ppm	CBIAC
1.2.2.1.1.5.7	QL	ppm	CBIAC
1.2.2.1.1.5.8	Selenide Experiments	ppm	CBIAC
1.2.2.1.1.5.9	Thiodigylcol	ppm	CBIAC
1.2.2.1.1.6	Choking Agents	ppm	CBIAC
1.2.2.1.1.6.1	Chlorine Gas	ppm	CBIAC
1.2.2.1.1.6.2	Chloropicrin	ppm	CBIAC
1.2.2.1.1.6.3	Diphosgene	ppm	CBIAC
1.2.2.1.1.6.4	Phosgene	ppm	CBIAC
1.2.2.1.1.6.5	Triphosgene	ppm	CBIAC
1.2.2.1.1.7	Herbicides	ppm	CBIAC
1.2.2.1.1.7.1	2,4 (Dichlorophenoxy) Acetic Acid	ppm	CBIAC
1.2.2.1.1.7.2	2,4,5 (Trichlorophenoxy) Acetic Acid	ppm	CBIAC
1.2.2.1.1.7.3	Agent Blue	ppm	CBIAC
1.2.2.1.1.7.4	Agent Orange	ppm	CBIAC

1.2.2.1.1.7.5	Agent Pink	ppm	CBIAC
1.2.2.1.1.7.6	Agent Purple	ppm	CBIAC
1.2.2.1.1.7.7	Agent White	ppm	CBIAC
1.2.2.1.1.7.8	Bromacil	ppm	CBIAC
1.2.2.1.1.7.9	Dioxin	ppm	CBIAC
1.2.2.1.1.8	Incapacitating Agents	ppm	CBIAC
1.2.2.1.1.8.1	3–Quinuclidinyl Benzilate	ppm	CBIAC
1.2.2.1.1.8.2	Blue–X	ppm	CBIAC
1.2.2.1.1.9	Nerve Agents	ppm	CBIAC
1.2.2.1.1.9.1	EA5365	ppm	CBIAC
1.2.2.1.1.9.2	Ethyl–P–Nitrophenyl Methylphosphonate	ppm	CBIAC
1.2.2.1.1.9.3	Flash	ppm	CBIAC
1.2.2.1.1.9.4	G Agents	ppm	CBIAC
1.2.2.1.1.9.4.1	Dimebu	ppm	CBIAC
1.2.2.1.1.9.4.2	G	ppm	CBIAC
1.2.2.1.1.9.4.3	GA	ppm	CBIAC
1.2.2.1.1.9.4.4	GB	ppm	CBIAC
1.2.2.1.1.9.4.5	GD	ppm	CBIAC
1.2.2.1.1.9.4.6	GE	ppm	CBIAC
1.2.2.1.1.9.4.7	GF	ppm	CBIAC
1.2.2.1.1.9.4.8	TGD	ppm	CBIAC
1.2.2.1.1.9.5	V Agents	ppm	CBIAC
1.2.2.1.1.9.5.1	TVX	ppm	CBIAC
1.2.2.1.1.9.5.2	V	ppm	CBIAC
1.2.2.1.1.9.5.3	VE	ppm	CBIAC
1.2.2.1.1.9.5.4	VG	ppm	CBIAC
1.2.2.1.1.9.5.5	VM	ppm	CBIAC
1.2.2.1.1.9.5.6	VS	ppm	CBIAC
1.2.2.1.1.9.5.7	VX	ppm	CBIAC
1.2.2.1.1.10	Other Chemical Agents	ppm	CBIAC
1.2.2.1.1.10.1	Acrylamides	ppm	CBIAC
1.2.2.1.1.10.2	Butyl Salicylate	ppm	CBIAC
1.2.2.1.1.10.3	Cadmium Chloride	ppm	CBIAC
1.2.2.1.1.10.4	Cadimium Fluoride	ppm	CBIAC
1.2.2.1.1.10.5	Chloroethylamine	ppm	CBIAC
1.2.2.1.1.10.6	Chloroethylmethylamine	ppm	CBIAC
1.2.2.1.1.10.7	Diisopropyl Fluorophosphate	ppm	CBIAC
1.2.2.1.1.10.8	Dimethylpolysulfide	ppm	CBIAC
1.2.2.1.1.10.9	Disulfur Decafluoride	ppm	CBIAC
1.2.2.1.1.10.10	Neostigmine	ppm	CBIAC
1.2.2.1.1.10.11	Phencyclidine	ppm	CBIAC
1.2.2.1.1.10.12	Sodium Arsenite	ppm	CBIAC
1.2.2.1.1.11	Psycho–Toxic Agents		CBIAC
1.2.2.1.1.11.1	Antidepressants	ppm	CBIAC

1.2.2.1.1.11.2	Antioxilytic Sedative Substances	ppm	CBIAC
1.2.2.1.1.11.3	Neuroleptics	ppm	CBIAC
1.2.2.1.1.11.4	Psychodisleptics	ppm	CBIAC
1.2.2.1.1.11.5	Psychostimulators	ppm	CBIAC
1.2.2.1.1.12	Tear Agents	ppm	CBIAC
1.2.2.1.1.12.1	2–Bromobenzylcyanide	ppm	CBIAC
1.2.2.1.1.12.2	Bromoacetone	ppm	CBIAC
1.2.2.1.1.12.3	Chloroacetophenone	ppm	CBIAC
1.2.2.1.1.12.4	Chloroacetophenone/ Chloroform Mixture	ppm	CBIAC
1.2.2.1.1.12.5	Chloroform	ppm	CBIAC
1.2.2.1.1.12.6	CN/Benzene/Carbon Tetrachloride Mixture	ppm	CBIAC
1.2.2.1.1.12.7	CN/Chloropicrin/Chloro–form Mixture	ppm	CBIAC
1.2.2.1.1.12.8	Ethylbromoacetate	ppm	CBIAC
1.2.2.1.1.12.9	Orthochlorobenzylidene Malonitrile	ppm	CBIAC
1.2.2.1.1.13	Vomiting Agents	ppm	CBIAC
1.2.2.1.1.13.1	Vomiting Agent Arsenicals	ppm	CBIAC
1.2.2.1.1.13.1.1	Diphenylaminoarsine	ppm	CBIAC
1.2.2.1.1.13.1.2	Diphenylaminochloroarsine	ppm	CBIAC
1.2.2.1.1.13.1.3	Diphenylchloroasine	ppm	CBIAC
1.2.2.1.1.13.1.4	Diphenylcyanoarsine	ppm	CBIAC
1.2.3	Electromagnetic	W/m^2	CBIAC
1.2.3.1	Electronic Warfare		CBIAC
1.2.3.2	Nuclear Electromag–netic Pulse (EMP)	$webers/m^3s$	CBIAC
1.2.3.3	Directed Energy		CBIAC
1.2.4	Constructed Obstacles		CBIAC
1.2.5	Obscurants and Illumination	ppm	CBIAC
1.2.5.1	Smoke	ppm	CBIAC
1.2.5.2	Chaff	ppm	CBIAC
1.2.5.3	Artificial Illumination	lux	CBIAC
1.2.6	Pressure	ppsm	NASA Bioastronautics Handbook
1.2.6.1	Dynamic	ppsm	NASA Bioastronautics Handbook
1.2.6.2	Static	ppsm	NASA Bioastronautics Handbook
1.2.7	Kinetic Projectiles	joules, kilogram	CSERIAC
1.2.8	Acceleration	m/sec^2	CSERIAC
1.2.8.1	Positive G	G*	Armstrong Aerospace Medical Research Laboratory (AAMRL); Boff, Kaufman, Lloyd, and Thomas (1986); Boff and Lincoln (1988); CSERIAC
1.2.8.1.1	Linear	m/sec^2 G_x, G_y, G_x	Armstrong Aerospace Medical Research Laboratory (AAMRL);

*$1G = 10^{-11}\ m^3/sec^2 \cdot kg$

			Boff, Kaufman, Lloyd, and Thomas (1986); Boff and Lincoln (1988); CSERIAC
1.2.8.1.2	Angular	radians per second2 G_{roll}, G_{pitch}, G_{yaw}	Armstrong Aerospace Medical Research Laboratory (AAMRL); Boff, Kaufman, Lloyd, and Thomas (1986); Boff and Lincoln (1988); CSERIAC
1.2.8.2	Reduced/Zero G	meters per second	Gazenko (1986); NASA Bioastronautics Handbook
1.2.9	Vibration	meters per second squared, Hertz	AAMRL/BB; International Standards Organization (ISO) Standard 263; Boff, et al. (1986); Boff and Lincoln (1988)
1.2.10	Confinement		CBIAC; CSERIAC; Evans, Stokols, and Carrere (1987a, 1987b, 1988)
1.2.11	Isolation	time since last human contact in seconds, distance in meters to nearest human	Evans, Stokols, and Carrere (1987a, 1987b, 1988); Shonyo (1978)
1.2.12	Man–Made Lighting	lux	Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
1.2.12.1	Type		Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
1.2.12.1.1	Fluorescent		Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
1.2.12.1.2	Incandescent		Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
1.2.12.2	Attributes		Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
1.2.12.2.1	Luminance	lux	Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
1.2.13	Noise	dB relative to 1 picowatt	AAMRL/BB; Boff, et al. (1986), Boff and Lincoln (1988); Harris (1979)
1.2.13.1	Duration	seconds	AAMRL/BB; Boff, et al. (1986), Boff and Lincoln (1988); Harris (1979)
1.2.13.1.1	Continuous	seconds	AAMRL/BB; Boff, et al. (1986), Boff and Lincoln (1988); Harris (1979)
1.2.13.1.2	Impulsive	seconds	AAMRL/BB; Boff, et al. (1986), Boff and Lincoln (1988); Harris (1979)
1.2.13.1.3	Intermittent	seconds	AAMRL/BB; Boff, et al. (1986), Boff and Lincoln (1988); Harris (1979)
1.2.13.1.4	Single	seconds	AAMRL/BB; Boff, et al. (1986), Boff and Lincoln (1988); Harris (1979)
1.2.13.2	Frequency	Hertz	AAMRL/BB; Boff, et al. (1986), Boff and Lincoln (1988); Harris (1979)
1.2.13.2.1	Constant	Hertz	AAMRL/BB; Boff, et al. (1986), Boff and Lincoln (1988); Harris (1979)
1.2.13.2.2	Variable	Hertz	AAMRL/BB; Boff, et al. (1986), Boff and Lincoln (1988); Harris (1979)
1.2.13.3	Intensity	dBA	AAMRL/BB; Boff, et al. (1986), Boff and Lincoln (1988); Harris (1979)
1.2.13.3.1	Constant	dBA	AAMRL/BB; Boff, et al. (1986), Boff and Lincoln (1988); Harris (1979)
1.2.13.3.2	Variable	dBA	AAMRL/BB; Boff, et al. (1986), Boff and Lincoln (1988); Harris (1979)

1.2.13.4	Medium	dBA	AAMRL/BB; Boff, et al. (1986), Boff and Lincoln (1988); Harris (1979)
1.2.13.4.1	Atmosphere	dBA	AAMRL/BB; Boff, et al. (1986), Boff and Lincoln (1988); Harris (1979)
1.2.13.4.2	Communication	dBA	AAMRL/BB; Boff, et al. (1986), Boff and Lincoln (1988); Harris (1979)
1.2.13.4.3	Hydrosphere	dBA	AAMRL/BB; Boff, et al. (1986), Boff and Lincoln (1988); Harris (1979)
1.2.13.5	Range	Hertz	AAMRL/BB; Boff, et al. (1986), Boff and Lincoln (1988); Harris (1979)
1.2.13.5.1	Infrasonic	Hertz	AAMRL/BB; Boff, et al. (1986), Boff and Lincoln (1988); Harris (1979)
1.2.13.5.2	Sonic	Hertz	AAMRL/BB; Boff, et al. (1986), Boff and Lincoln (1988); Harris (1979)
1.2.13.5.3	Ultrasonic	Hertz	AAMRL/BB; Boff, et al. (1986), Boff and Lincoln (1988); Harris (1979)
1.2.13.6	Spectrum	Hertz	AAMRL/BB; Boff, et al. (1986), Boff and Lincoln (1988); Harris (1979)
1.2.13.6.1	Broadband	Hertz	AAMRL/BB; Boff, et al. (1986), Boff and Lincoln (1988); Harris (1979)
1.2.13.6.2	Narrowband	Hertz	AAMRL/BB; Boff, et al. (1986), Boff and Lincoln (1988); Harris (1979)
1.2.13.6.3	Pure	Hertz	AAMRL/BB; Boff, et al. (1986), Boff and Lincoln (1988); Harris (1979)
1.2.14	Altitude	meters MSL	AAMRL/BB; Boff, et al. (1986), Boff and Lincoln (1988)
1.2.14.1	Reduced O_2	ppm	AAMRL/BB; Boff, et al. (1986), Boff and Lincoln (1988)
1.2.14.2	Partial Pressure	ppm	AAMRL/BB; Boff, et al. (1986), Boff and Lincoln (1988)
1.3	***Operational Environment***		CSERIAC
1.3.1	Mission constraints		CSERIAC
1.3.1.1	Time	seconds	CSERIAC
1.3.1.2	Space	meters	CSERIAC
1.3.1.3	Support		CSERIAC
1.3.1.4	Use Of Weapons (Nuclear, Chemical)		CSERIAC
1.3.2	Enemy Situation		Dynamics Research Corporation (1989)
1.3.2.1	Disposition		Dynamics Research Corporation (1989)
1.3.2.1.1	Location (Grid, Altitude)		Dynamics Research Corporation (1989)
1.3.2.1.2	Movement (Direction, Rate)		Dynamics Research Corporation (1989)
1.3.2.1.3	Density (Point, Area)		Dynamics Research Corporation (1989)
1.3.2.2	Composition		Dynamics Research Corporation (1989)
1.3.2.2.1	Task Organization		Dynamics Research Corporation (1989)
1.3.2.2.2	Equipment Types and Characteristics		Dynamics Research Corporation (1989)
1.3.2.2.3	Configuration (Mission Equipment, Loads)		Dynamics Research Corporation (1989)
1.3.2.3	Strength		Dynamics Research Corporation (1989)
1.3.2.3.1	Unit Strength (Committed, Reinforcements)		Dynamics Research Corporation (1989)

1.3.2.3.1.1	Personnel (Percent of Authorized, Moral, Training)	Dynamics Research Corporation (1989)
1.3.2.3.1.2	Equipment (Percent Combat Ready)	Dynamics Research Corporation (1989)
1.3.2.3.2	Support Status	Dynamics Research Corporation (1989)
1.3.2.3.2.1	Combat Support (Air, Nuclear, Chemical)	Dynamics Research Corporation (1989)
1.3.2.3.2.2	Combat Service Support	Dynamics Research Corporation (1989)
1.3.2.4	Significant Activities	Dynamics Research Corporation (1989)
1.3.2.4.1	Recent Operations	Dynamics Research Corporation (1989)
1.3.2.4.2	Tempo of Operations	Dynamics Research Corporation (1989)
1.3.2.5	Vulnerabilities	Dynamics Research Corporation (1989)
1.3.2.5.1	Protection Levels (Ballistic, Chemical, Electronic)	Dynamics Research Corporation (1989)
1.3.2.5.2	Concealment (Positioning)	Dynamics Research Corporation (1989)
1.3.2.5.3	Security Procedures	Dynamics Research Corporation (1989)
1.3.3	Friendly Situation	Dynamics Research Corporation (1989)
1.3.3.1	Disposition	Dynamics Research Corporation (1989)
1.3.3.1.1	Location (Grid, Altitude)	Dynamics Research Corporation (1989)
1.3.3.1.2	Movement (Direction, Rate)	Dynamics Research Corporation (1989)
1.3.3.1.3	Density (Point, Area)	Dynamics Research Corporation (1989)
1.3.3.2	Composition	Dynamics Research Corporation (1989)
1.3.3.2.1	Task Organization	Dynamics Research Corporation (1989)
1.3.3.2.2	Equipment Types and Characteristics	Dynamics Research Corporation (1989)
1.3.3.2.3	Configuration (Mission Equipment, Loads)	Dynamics Research Corporation (1989)
1.3.3.3	Strength	Dynamics Research Corporation (1989)
1.3.3.3.1	Unit Strength (Committed,	Dynamics Research Corporation (1989)
1.3.3.3.1.1	Personnel (Percent Of Authorized, Morale, Training)	Dynamics Research Corporation (1989)
1.3.3.3.1.2	Equipment (Percent Combat Ready)	Dynamics Research Corporation (1989)
1.3.3.3.2	Support Status	Dynamics Research Corporation (1989)
1.3.3.3.2.1	Combat Support (Air, Nuclear, Chemical)	Dynamics Research Corporation (1989)
1.3.3.3.2.2	Combat Service Support	Dynamics Research Corporation (1989)
1.3.3.4	Significant Activities	Dynamics Research Corporation (1989)
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1.3.4.3.1.1.1	Formulate Request for Strategic Deployment of Joint/Combined Forces to Theater of Operations	TRADOC Pam 11–9
1.3.4.3.1.1.2	Conduct Intra–Theater of Operations Deployment of Forces	TRADOC Pam 11–9
1.3.4.3.1.2	Conduct Operational Maneuver	TRADOC Pam 11–9
1.3.4.3.1.2.1	Transition To and From Tactical Battle Formations	TRADOC Pam 11–9
1.3.4.3.1.2.2	Posture Forces for Operational Formations	TRADOC Pam 11–9
1.3.4.3.1.2.3	Conduct Operations In Depth	TRADOC Pam 11–9
1.3.4.3.1.3	Provide Operational Mobility	TRADOC Pam 11–9
1.3.4.3.1.3.1	Overcome Operationally Significant Obstacles	TRADOC PAM 11–9
1.3.4.3.1.3.2	Enhance Movement of Operational Forces	TRADOC Pam 11–9
1.3.4.3.1.4	Provide Operational Countermobility	TRADOC Pam 11–9
1.3.4.3.1.4.1	Select Location For Opera–tional Forces	TRADOC Pam 11–9
1.3.4.3.1.4.2	Emplace Operational Sys–tems of Obstacles	TRADOC Pam 11–9
1.3.4.3.1.5	Control Operationally Signi–ficant Area	TRADOC Pam 11–9
1.3.4.3.2	Operational Fires	TRADOC Pam 11–9
1.3.4.3.2.1	Process Operational Targets	TRADOC Pam 11–9
1.3.4.3.2.1.1	Select Operational Targets For Attack	TRADOC Pam 11–9
1.3.4.3.2.1.2	Allocate Joint/Combined Operational Fires Resources	TRADOC Pam 11–9
1.3.4.3.2.2	Attack Operational Targets	TRADOC Pam 11–9
1.3.4.3.2.2.1	Conduct Lethal Attack On Operational Targets	TRADOC Pam 11–9
1.3.4.3.2.2.1.1	Conduct Attack With Sur–face/Subsurface Based Operational Fires	TRADOC Pam 11–9
1.3.4.3.2.2.1.2	Conduct Aerospace Op–erational Fires Attack	TRADOC Pam 11–9
1.3.4.3.2.2.2	Conduct Nonlethal Attack On Operational Targets	TRADOC Pam 11–9
1.3.4.3.2.2.2.1	Reduce Enemy Opera–tional Force Effectiveness	TRADOC Pam 11–9
1.3.4.3.2.2.2.2	Reduce Enemy Critical Facilities Effectiveness	TRADOC Pam 11–9
1.3.4.3.2.2.2.3	Integrate Operational Fires	TRADOC Pam 11–9
1.3.4.3.3	Operational Protection	TRADOC Pam 11–9
1.3.4.3.3.1	Provide Operational Air Defense	TRADOC Pam 11–9
1.3.4.3.3.1.1	Process Operational Air Defense Targets	TRADOC Pam 11–9

1.3.4.3.3.1.1.1	Allocate Targets for Attack	TRADOC Pam 11–9
1.3.4.3.3.1.1.2	Integrate Joint/Combined Operational Air Defense Forces	TRADOC Pam 11–9
1.3.4.3.3.1.2	Provide Airspace Control	TRADOC Pam 11–9
1.3.4.3.3.1.2.1	Employ Positive Control Measures	TRADOC Pam 11–9
1.3.4.3.3.1.2.2	Employ Procedural Control Measures	TRADOC Pam 11–9
1.3.4.3.3.1.3	Attack Enemy Air Defense Targets	TRADOC Pam 11–9
1.3.4.3.3.1.3.1	Conduct Lethal Attack On Operational Air Defense Targets	TRADOC Pam 11–9
1.3.4.3.3.1.3.2	Conduct Nonlethal Attack On Operational Air Defense Targets	TRADOC Pam 11–9
1.3.4.3.3.2	Provide Protection For Operational Forces and Means	TRADOC Pam 11–9
1.3.4.3.3.2.1	Prepare Operationally Sig–nificant Fortifications	TRADOC Pam 11–9
1.3.4.3.3.2.2	Remove Operationally Sig–nificant Hazards	TRADOC Pam 11–9
1.3.4.3.3.2.3	Protect Use of Electromag–netic Spectrum	TRADOC Pam 11–9
1.3.4.3.3.3	Employ Operations Security	TRADOC Pam 11–9
1.3.4.3.3.3.1	Employ Signal Security (Sigsec)	TRADOC Pam 11–9
1.3.4.3.3.3.2	Employ Concealment Tech–niques	TRADOC Pam 11–9
1.3.4.3.3.4	Conduct Deception in Sup–port of Campaigns and Major Operations	TRADOC Pam 11–9
1.3.4.3.3.4.1	Protect Details of Campaigns and Major Operations	TRADOC Pam 11–9
1.3.4.3.3.4.2	Spread Misinformation Regarding Conduct of Operations	TRADOC Pam 11–9
1.3.4.3.3.4.3	Assess Effect of Operational Deception Plan	TRADOC Pam 11–9
1.3.4.3.3.5	Provide Security For Operational Forces and Means	TRADOC Pam 11–9
1.3.4.3.4	Operational Command and Control	TRADOC Pam 11–9
1.3.4.3.4.1	Acquire and Communicate Operational Level Informa–tion and Maintain Status	TRADOC Pam 11–9
1.3.4.3.4.1.1	Communicate Operational Information	TRADOC Pam 11–9
1.3.4.3.4.1.2	Manage Means of Commu–nicating Operational Information	TRADOC Pam 11–9
1.3.4.3.4.1.3	Maintain Operational Information and Force Status	TRADOC Pam 11–9
1.3.4.3.4.1.4	Monitor Strategic Situation	TRADOC Pam 11–9

1.3.4.3.4.2	Assess Operational Situation	TRADOC Pam 11–9
1.3.4.3.4.2.1	Review Current Situation	TRADOC Pam 11–9
1.3.4.3.4.2.2	Project Future Campaigns or Major Operations	TRADOC Pam 11–9
1.3.4.3.4.2.3	Decide on Need for Action or Change	TRADOC Pam 11–9
1.3.4.3.4.3	Determine Operational Actions	TRADOC Pam 11–9
1.3.4.3.4.3.1	Issue Planning Guidance	TRADOC Pam 11–9
1.3.4.3.4.3.2	Develop Courses of Action	TRADOC Pam 11–9
1.3.4.3.4.3.3	Analyze Courses of Action	TRADOC Pam 11–9
1.3.4.3.4.3.4	Compare Courses of Action	TRADOC Pam 11–9
1.3.4.3.4.3.5	Select or Modify Course of Action	TRADOC Pam 11–9
1.3.4.3.4.3.6	Finalize Commander's Concept and Intent	TRADOC Pam 11–9
1.3.4.3.4.4	Direct and Lead Subordinate Operational Forces	TRADOC Pam 11–9
1.3.4.3.4.4.1	Prepare Campaign or Major Operations Plans and Orders	TRADOC Pam 11–9
1.3.4.3.4.4.1.1	Develop and Complete Operational Plans and Orders	TRADOC Pam 11–9
1.3.4.3.4.4.1.2	Coordinate Service Components, Theater Army, and Other Support	TRADOC Pam 11–9
1.3.4.3.4.4.1.3	Approve Plans and Orders	TRADOC Pam 11–9
1.3.4.3.4.4.2	Issue Plans and Orders	TRADOC Pam 11–9
1.3.4.3.4.4.3	Provide Operational Command Presence	TRADOC Pam 11–9
1.3.4.3.4.4.4	Synchronize Operations	TRADOC Pam 11–9
1.3.4.3.4.5	Employ C^3 Centimeters	TRADOC Pam 11–9
1.3.4.3.5	Operational Intelligence	TRADOC Pam 11–9
1.3.4.3.5.1	Collect Operational Information	TRADOC Pam 11–9
1.3.4.3.5.1.1	Collect Information on Operational Situation and Hazards	TRADOC Pam 11–9
1.3.4.3.5.1.2	Collect Information on Operational Targets	TRADOC Pam 11–9
1.3.4.3.5.2	Process Operational Information	TRADOC Pam 11–9
1.3.4.3.5.2.1	Evaluate Operational Threat Information	TRADOC Pam 11–9
1.3.4.3.5.2.2	Analyze Area of Operations	TRADOC Pam 11–9
1.3.4.3.5.2.3	Integrate Operational Intelligence	TRADOC Pam 11–9
1.3.4.3.5.2.3.1	Develop Enemy Operational Intentions	TRADOC Pam 11–9
1.3.4.3.5.2.3.2	Develop Operational Target Information	TRADOC Pam 11–9
1.3.4.3.5.2.4	Develop Indications and Warning	TRADOC Pam 11–9

1.3.4.3.5.2.5	Identify Friendly Vulnerables	TRADOC Pam 11–9
1.3.4.3.5.3	Prepare Operational Intelligence Reports	TRADOC Pam 11–9
1.3.4.3.6	Operational Support	TRADOC Pam 11–9
1.3.4.3.6.1	Arm	TRADOC Pam 11–9
1.3.4.3.6.2	Fuel	TRADOC Pam 11–9
1.3.4.3.6.3	Fix/Maintain Equipment	TRADOC Pam 11–9
1.3.4.3.6.4	Man the Force	TRADOC Pam 11–9
1.3.4.3.6.4.1	Provide Field, Personnel and Health Services	TRADOC Pam 11–9
1.3.4.3.6.4.2	Reconstitute Forces	TRADOC Pam 11–9
1.3.4.3.6.4.3	Train Units and Personnel	TRADOC Pam 11–9
1.3.4.3.6.4.4	Conduct Theater of Operations Reception Operations	TRADOC Pam 11–9
1.3.4.3.6.5	Distribute	TRADOC Pam 11–9
1.3.4.3.6.5.1	Provide Movement Services	TRADOC Pam 11–9
1.3.4.3.6.5.2	Supply Operational Forces	TRADOC Pam 11–9
1.3.4.3.6.6	Maintain Sustainment Base(s)	TRADOC Pam 11–9
1.3.4.3.6.6.1	Recommend Number and Location of Sustaining Base(s)	TRADOC Pam 11–9
1.3.4.3.6.6.2	Provide Sustainment Engineering	TRADOC Pam 11–9
1.3.4.3.6.6.3	Provide Law Enforcement and Prisoner Control	TRADOC Pam 11–9
1.3.4.3.6.7	Conduct Civil Affairs	TRADOC Pam 11–9
1.3.4.3.6.8	Evacuate Noncombatants from Theater of Operations	TRADOC Pam 11–9
1.3.5	Level Of Activity	Joint Chiefs of Staff Publication 3–0
1.3.5.1	War	Joint Chiefs of Staff Publication 3–0
1.3.5.2	Conflict	Joint Chiefs of Staff Publication 3–0
1.3.5.3	Peacetime Competition	Joint Chiefs of Staff Publication 3–0
1.3.5.4	Routine Peaceful Competition	Joint Chiefs of Staff Publication 3–0
1.3.5.5	Terrorism	Joint Chiefs of Staff Publication 3–0
1.3.5.6	Counterdrug	Joint Chiefs of Staff Publication 3–0
1.3.5.7	Suppression	DNA (1978)
1.3.5.8	Surprise	DNA (1978)
1.3.6	Level of Conflict	Joint Chiefs of Staff Publication 3–0
1.3.6.1	High Intensity	Joint Chiefs of Staff Publication 3–0
1.3.6.2	Mid Intensity	Joint Chiefs of Staff Publication 3–0
1.3.6.3	Low Intensity	Joint Chiefs of Staff Publication 3–0
1.3.7	Defense Readiness Condition	Joint Chiefs of Staff Publication 1–02
1.3.7.1	DEFCON (5)	Joint Chiefs of Staff Publication 1–02
1.3.7.2	DEFCON (4)	Joint Chiefs of Staff Publication 1–02
1.3.7.3	DEFCON (3)	Joint Chiefs of Staff Publication 1–02
1.3.7.4	DEFCON (2)	Joint Chiefs of Staff Publication 1–02

1.3.7.5	DEFCON (1)		Joint Chiefs of Staff Publication 1–02
1.4	***Interior Environment***		CSERIAC
1.4.1	Facility Description		Harrigan (1974)
1.4.1.1	Facility Units		Harrigan (1974)
1.4.1.2	User Categories		Harrigan (1974)
1.4.1.3	Furnishing Allocations		Harrigan (1974)
1.4.1.4	Facility Management Plan		Harrigan (1974)
1.4.1.5	Alteration Expectancies		Harrigan (1974)
1.4.1.6	User Activity Descriptions		Harrigan (1974)
1.4.2	Sociocultural Character		Harrigan (1974)
1.4.2.1	Cultural Phenomena		Harrigan (1974)
1.4.2.2	Social Organization		Harrigan (1974)
1.4.2.3	Effects of Nonimplementation		Harrigan (1974)
1.4.3	User Activity Support		Harrigan (1974)
1.4.3.1	Furnishings and Hardware Design Criteria		Harrigan (1974)
1.4.3.2	Furnishings, Hardware, and User Placement		Harrigan (1974)
1.4.3.3	Ambient Environmental Criteria		Harrigan (1974)
1.4.3.4	Convenience, Safety, and Security		Harrigan (1974)
1.4.4	Surfaces		Harrigan (1974)
1.4.4.1	User Effects Possibilities		Harrigan (1974)
1.4.4.2	Color, Texture, and Pattern		Harrigan (1974)
1.4.4.3	Durability and Maintainability		Harrigan (1974)
1.4.5	Circulation		Harrigan (1974)
1.4.5.1	Information Flow		Harrigan (1974)
1.4.5.2	User Flow		Harrigan (1974)
1.4.5.3	Equipment and Material Flow		Harrigan (1974)
1.4.5.4	Movement Priorities		Harrigan (1974)
1.4.5.5	Circulation Pattern Summary		Harrigan (1974)
1.4.6	Spatial Configurations and Arrangements		Harrigan (1974)
1.4.6.1	Space Requirements		Harrigan (1974)
1.4.6.2	Unit Adjacencies		Harrigan (1974)
1.4.6.3	Candidate Spatial Config–urations and Arrangements		Harrigan (1974)
1.4.7	Location		Harrigan (1974)
1.4.7.1	Area and Regional Integration		Harrigan (1974)
1.4.7.2	Facility Orientations and Adjaciencies		Harrigan (1974)
1.4.7.3	Transporation Interface		Harrigan (1974)
2	**Operator**		CSERIAC
2.1	***Physical Characteristics***		CSERIAC
2.1.1	Age	years	Boff, et al. (1986); Boff and Lincoln (1988); Craik and Rabinowitz (1985);

			Denny (1985); Fishburne and Parkison (1985); Gubser (1984); Guralnik, Branch, Cummings, and Curb (1989); Hartley and Anderson (1983); McDowd and Craik (1988); Mertens and Boone (1988); Milligan, Powell, and Furchtgott (1981); Ord and Lancaster (1971); Salthouse, Kaulser, and Saults (1988); Sekuler, Kline, and Dismukes (1982); Shaw and Craik (1989); Wickens, Braune, and Stokes (1987)
2.1.2	Anthropometry		CAR; Combiman; Crew Chief; CSERIAC; SAMMIE
2.1.2.1	Height		CAR; Combiman; Crew Chief; CSERIAC; SAMMIE
2.1.2.1.1	Sitting Eye Height		CAR; Combiman; Crew Chief; CSERIAC; SAMMIE
2.1.2.2	Weight		CAR; Combiman; Crew Chief; CSERIAC; SAMMIE
2.1.2.3	Physiology		ARIEM
2.1.2.3.1	Body Surface Area	square meters	ARIEM
2.1.2.3.2	Effective Surface Area for Evaporation	square meters	ARIEM
2.1.2.3.3	Average Skin Temperature	degrees Celsius	ARIEM
2.1.2.3.4	Water Vapor Pressure at the Skin		ARIEM
2.1.2.3.5	Body Core Temperature	mm Hg	ARIEM; Krahenbuhl, Harris, Constable, Morgan, and Allen (1989)
2.1.2.3.6	Body Needs		Phillips, Lombardi, and Eyler (1989); Tharion, Szylk, and Rauch (1989)
2.1.2.3.6.1	Fluid Intake	fluid ounces per hour	Phillips, Lombardi, and Eyler (1989)
2.1.2.3.6.2	Eating	calories	Phillips, Lombardi, and Eyler (1989)
2.1.2.3.6.3	Elimination		Phillips, Lombardi, and Eyler (1989)
2.1.2.3.7	Heart Rate	beats per minute	CSERIAC
2.1.2.3.8	Blood Pressure	mm Hg	CBIAC
2.1.2.3.8.1	Diastolic Pressure	mm Hg	CBIAC
2.1.2.3.8.2	Systolic Pressure	mm Hg	CBIAC
2.1.2.3.9	Respiration		CBIAC
2.1.2.3.9.1	Hyperventilation		CBIAC
2.1.2.3.9.2	Respiratory Burden		CBIAC
2.1.2.3.9.3	VO Max		CBIAC
2.1.2.3.10	Biorhythms		Mosier (1974)
2.1.2.4	Physical Strength		Schellhous (1982)
2.1.2.5	Feet		CSERIAC
2.1.2.5.1	Agility		CSERIAC
2.1.2.5.2	Dominance		CSERIAC
2.1.2.5.3	Lift Strength		CSERIAC
2.1.2.6	Hands		CSERIAC
2.1.2.6.1	Dominance		CSERIAC
2.1.2.6.2	Flexibility		CSERIAC
2.1.2.6.3	Grip Strength		CSERIAC

2.1.2.7	Voice		CSERIAC
2.1.2.8	Legs		CSERIAC
2.1.2.8.1	Endurance		CSERIAC
2.1.2.8.2	Strength		CSERIAC
2.1.2.9	Arms		CSERIAC
2.1.2.9.1	Endurance		CSERIAC
2.1.2.9.2	Length		CSERIAC
2.1.3	Fatiuability	joules per second	ARIEM; TRADOC (1979)
2.1.3.1	Physical Neural Impedance		ARIEM; TRADOC (1979)
2.1.3.2	Mental		ARIEM; TRADOC (1979)
2.1.3.2.1	Neuropsychiatric Fatalities		ARIEM; TRADOC (1979)
2.1.3.3	Sleep Deprivation		Hartman and Cantrell (1967); NASA/Ames; University of California, Santa Barbara
2.1.4	Gender		Human Engineering Laboratory (HEL)
2.1.4.1	Female		HEL
2.1.4.2	Male		HEL
2.2	***Mental State***		CSERIAC
2.2.1	Attention Span	seconds	CSERIAC
2.2.2	Drugs		Naval Aerospace Medical Institute (NAMI); SAM; Walter Reed Research Institute; OMPAT
2.2.2.1	Type		NAMI SAM; Walter Reed Research Institute; OMPAT
2.2.2.1.1	Nerve Agent Antidotes		Kobrick, Johnson, and McMenemy (1989, 1990); Kolka and Cadarette (1988)
2.2.2.2	Attributes		NAMI; SAM; Walter Reed Research Institute; OMPAT
2.2.2.2.1	Dosage		NAMI; SAM; Walter Reed Research Institute; OMPAT
2.2.2.2.2	Number of Days Since Last		NAMI);SAM; Walter Reed Research Institute; OMPAT
2.2.2.2.3	Number of Days Taken		NAMI; SAM; Walter Reed Research Institute; OMPAT
2.2.3	Memory		Boff, et al. (1986); Boff and Lincoln (1988)
2.2.3.1	Long Term		Boff, et al. (1986); Boff and Lincoln (1988)
2.2.3.1.1	Training		Aeronautical Systems Division; Army Research Institute Combat Training Center (CTC) Archives; Army Research Institute for the Behavioral and Social Sciences; ARIEM; Chief of Naval Operations; Defense Training and Performance Data Center; Human Resources Laboratory (HRL); IMPACTS; MANPRINT; Naval Aerospace Medical Research Laboratory; Naval Personnel Research and Development Center; Naval Training Systems Center; Training Performance Data Center (TPDC)

2.2.3.1.1.1	Type Of Training	Aeronautical Systems Division; Army Research Institute Combat Training Center (CTC) Archives; Army Research Institute for the Behavioral and Social Sciences; ARIEM; Chief of Naval Operations; Defense Training and Performance Data Center; Human Resources Laboratory (HRL); IMPACTS; MANPRINT; Naval Aerospace Medical Research Laboratory; Naval Personnel Research and Development Center; Naval Training Systems Center; Training Performance Data Center (TPDC)
2.2.3.1.1.2	Amount Of Training	Aeronautical Systems Division; Army Research Institute Combat Training Center (CTC) Archives; Army Research Institute for the Behavioral and Social Sciences; ARIEM; Chief of Naval Operations; Defense Training and Performance Data Center; Human Resources Laboratory (HRL); IMPACTS; MANPRINT; Naval Aerospace Medical Research Laboratory; Naval Personnel Research and Development Center; Naval Training Systems Center; Training Performance Data Center (TPDC)
2.2.3.1.1.3	Skill Level	Aeronautical Systems Division; Army Research Institute Combat Training Center (CTC) Archives; Army Research Institute for the Behavioral and Social Sciences; ARIEM; Chief of Naval Operations; Defense Training and Performance Data Center; Human Resources Laboratory (HRL); IMPACTS; MANPRINT; Naval Aerospace Medical Research Laboratory; Naval Personnel Research and Development Center; Naval Training Systems Center; Training Performance Data Center (TPDC)
2.2.3.1.1.4	Frequency	Aeronautical Systems Division; Army Research Institute Combat Training Center (CTC) Archives; Army Research Institute for the Behavioral and Social Sciences; ARIEM; Chief of Naval Operations; Defense Training and Performance Data Center; Human Resources Laboratory (HRL); IMPACTS; MANPRINT; Naval Aerospace Medical Research Laboratory; Naval Personnel Research and Development Center; Naval Training Systems Center; Training Performance Data Center (TPDC)
2.2.3.1.1.5	Recency	Aeronautical Systems Division; Army Research Institute Combat Training Center (CTC) Archives; Army Research Institute for the Behavioral and Social Sciences; ARIEM; Chief of Naval Operations; Defense Training and Performance Data Center; Human Resources

			Laboratory (HRL); IMPACTS; MANPRINT; Naval Aerospace Medical Research Laboratory; Naval Personnel Research and Development Center; Naval Training Systems Center; Training Performance Data Center (TPDC)
2.2.3.1.2	Combat Experience	months	Wicks, et al. (1989)
2.2.3.2	Short Term		Boff, et al. (1986); Boff and Lincoln (1988)
2.2.3.2.1	Number of Items Stored		Boff, et al. (1986); Boff and Lincoln (1988)
2.2.4	Personality Traits		Trevor Dupuy
2.2.4.1	Perceived Probability of Success		CSERIAC
2.2.4.2	Leadership		CSERIAC
2.2.4.3	Courage/Cowardice		CSERIAC
2.2.4.4	Machoism		CSERIAC
2.2.4.5	Will to Live		CSERIAC
2.2.4.6	Stubbornness		CSERIAC
2.2.4.7	Birth Order		Bassett, Gayton, Blanchard, and Ozmon (1977); Clum and Clum (1970); Dooley and Murthy (1974); Payne (1971); Prunkl (1969); Sharan, Amir, and Kovarsky (1969)
2.2.5	Work Schedule		School of Aerospace Medicine
2.2.5.1	Days On Duty		CSERIAC
2.2.5.2	Mission Duration		CSERIAC
2.2.5.3	Rest Periods		CSERIAC
2.2.5.3.1	Duration		CSERIAC
2.2.5.3.2	Frequency		CSERIAC
2.2.5.4	Rotation of Task		Wicks, et al. (1989)
2.2.6	Experience		Aeronautical Systems Division (ASD) MPT Information Directorate; Chief of Naval Operations HARDMAN Development Office; Integrated Manpower Personnel and Comprehensive Training and Safety (IMPACTS)
2.2.6.1	Street Smart		CSERIAC
2.2.6.2	New Guy Factor		CSERIAC
2.2.6.3	Understanding of Task		Wick, Kash, Ramirez, and Zimmer (1989)
2.2.7	Abilities		CSERIAC
2.2.7.1	Decisionmaking		CSERIAC
2.2.7.1.1	Flexibility of Closure		Levine, Romashko, and Fleishman (1973)
2.2.7.2	Detection		CSERIAC
2.2.7.2.1	Perceptual Speed		Levine, Romashko, and Fleishman (1973)
2.2.7.2.2	Response Orientation		Fleishman (1975)
2.2.7.3	Fine Manipulation		CSERIAC
2.2.7.3.1	Manual Dexterity		Fleishman (1975)
2.2.7.3.2	Finger Dexterity		Fleishman (1975)

2.2.7.4	Gross Manipulation		CSERIAC
2.2.7.4.1	Multilimb Coordination		Fleishman (1975)
2.2.7.4.2	Speed of Arm Movement		Fleishman (1975)
2.2.7.4.3	Rate Control		Fleishman (1975)
2.2.7.4.4	Arm Steadiness		Fleishman (1975)
2.2.7.4.5	Wrist–finger Speed		Fleishman (1975)
2.2.7.4.6	Aiming		Fleishman (1975)
2.2.7.5	Numeric Manipulation		CSERIAC
2.2.7.6	Probability Estimation		CSERIAC
2.2.7.7	Recognition		CSERIAC
2.2.7.8	Team Coordination		CSERIAC
2.2.7.9	Time Estimation		CSERIAC
2.2.7.10	Time Sharing		Levine, Romashko, and Fleishman (1973)
2.2.7.10.1	Selective Attention		Levine, Romashko, and Fleishman (1973)
2.2.7.11	Tracking		CSERIAC
2.2.7.11	Communication		CSERIAC
2.2.7.12	Space Estimation		CSERIAC
2.2.8	Education		CSERIAC
2.2.8.1	Reading Level		CSERIAC
2.2.8.2	Armed Services Vocational Aptitude Test (ASVAT)		Defense Manpower Data Center (DMDC)
2.2.9	Intelligence		DMDC
2.2.10	Clothing		ARIEM
2.2.10.1	Type		ARIEM
2.2.10.1.1	Shorts		ARIEM
2.2.10.1.2	Fatigues		ARIEM
2.2.10.1.2.1	Desert Camouflage		ARIEM
2.2.10.1.2.2	Desert Tan		ARIEM
2.2.10.1.2.3	Tropical Camouflage		ARIEM
2.2.10.1.2.4	Tropical Fatigues		ARIEM
2.2.10.1.2.5	Utility Fatigues		ARIEM
2.2.10.1.3	Protective Suit		ARIEM
2.2.10.1.3.1	Aviator's Suit		ARIEM
2.2.10.1.3.2	Firefighters Suit		ARIEM
2.2.10.1.3.3	Fuel Handler's Suit		ARIEM
2.2.10.1.4	MOPP	IM/clo	Abel (1987); ARIEM; Army Natrick Research, Development, and Evaluation Center; Fine and Kobrick (1985); Kelly, Englund, Ryman, Yeager, and Sucec (1988); Kobrick and Sleeper (1985); Szlyk, Sils, Francesconi, and Hubbard (1989); Ursano (1988).
2.2.10.1.4.1	MOPP I	IM/clo	Abel (1987); ARIEM; Army Natrick Research, Development, and Evaluation Center; Fine and Kobrick (1985); Kelly, Englund, Ryman, Yeager, and Sucec (1988);

			Kobrick and Sleeper (1985); Szlyk, Sils, Francesconi, and Hubbard (1989); Ursano (1988).
2.2.10.1.4.2	MOPP II	IM/clo	Abel (1987); ARIEM; Army Natrick Research, Development, and Evaluation Center; Fine and Kobrick (1985); Kelly, Englund, Ryman, Yeager, and Sucec (1988); Kobrick and Sleeper (1985); Szlyk, Sils, Francesconi, and Hubbard (1989); Ursano (1988).
2.2.10.1.4.3	MOPP III	IM/clo	Abel (1987); ARIEM; Army Natrick Research, Development, and Evaluation Center; Fine and Kobrick (1985); Kelly, Englund, Ryman, Yeager, and Sucec (1988); Kobrick and Sleeper (1985); Szlyk, Sils, Francesconi, and Hubbard (1989); Ursano (1988).
2.2.10.1.4.4	MOPP IV	IM/clo	Abel (1987); ARIEM; Army Natrick Research, Development, and Evaluation Center; Fine and Kobrick (1985); Kelly, Englund, Ryman, Yeager, and Sucec (1988); Kobrick and Sleeper (1985); Szlyk, Sils, Francesconi, and Hubbard (1989); Ursano (1988).
2.2.10.2	Attributes		ARIEM
2.2.10.2.1	Clothing Weight	kg	ARIEM
2.2.10.2.2	Total Insulation Including Air Layer and Intrinsic Clothing		ARIEM
2.2.10.2.3	Permeability Index		ARIEM
2.2.11	Emotions		CSERIAC
2.2.11.1	Fear		CSERIAC
2.2.11.2	Anger		CSERIAC
2.2.11.3	Frustration		CSERIAC
2.2.11.4	Hate		CSERIAC
2.2.11.5	Altruism		CSERIAC
2.2.11.6	Sadness/Grief		CSERIAC
2.2.11.7	Anxiety		CSERIAC
2.2.11.8	Patriotism		CSERIAC
2.2.11.9	Willingness To Fight		CSERIAC
2.2.12	Level Of Responsibility		Wicks, et al. (1989)
2.3	***Senses***		Boff, et al. (1986); Boff and Lincoln (1988); HOS; Van Cott and Kinkade (1972)
2.3.1	Auditory Sense		Boff, et al. (1986)
2.3.1.1	Acuity		Boff, et al. (1986)
2.3.1.2	Biaural		Boff, et al. (1986)
2.3.1.3	Monaural		Boff, et al. (1986)
2.3.1.4	Tone Perception		Boff, et al. (1986)
2.3.2	Olfactory Sense		Boff, et al. (1986)
2.3.3	Tactile Sense		Boff, et al. (1986)

2.3.4	Vision		Boff, et al. (1986)
2.3.4.1	Accommodation		Boff, et al. (1986)
2.3.4.2	Acuity		Boff, et al. (1986)
2.3.4.3	Binocular		Boff, et al. (1986)
2.3.4.4	Color Perception		Boff, et al. (1986)
2.3.4.5	Convergence		Boff, et al. (1986)
2.3.4.6	Monocular		Boff, et al. (1986)
2.4	***Health***		Fort Sam Houston
2.4.1	Injury		Fort Sam Houston
2.4.1.1	Rash		Fort Sam Houston
2.4.1.2	Frostbite		Fort Sam Houston
2.4.1.2.1	Hypothermia		CBIAC
2.4.1.3	Sunburn		CBIAC
2.4.1.4	Wounds		CBIAC
2.4.1.4.1	Blisters		CBIAC
2.4.1.4.2	Burns		CBIAC
2.4.1.4.3	Hemmorage		CBIAC
2.4.1.5	Allergic Reactions		CBIAC
2.4.1.6	Temporary Deafness		CBIAC
2.4.2	Sickness		CBIAC
2.4.2.1	Disease		CBIAC
2.4.2.1.1	Dysentery		CSERIAC
2.4.2.1.2	Diarrhea		CSERIAC
2.4.2.1.3	Flu		CSERIAC
2.4.2.1.4	Malaria		CSERIAC
2.4.2.1.5	Trenchfoot		CSERIAC
2.4.2.1.6	Yellow Fever		CSERIAC
2.4.2.2	Dehydration	liters	ARIEM; CBIAC
2.4.2.2.1	Diarrhea		CBIAC
2.4.2.2.2	Membrane Dehydration		CBIAC
2.4.2.2.3	Perspiration		CBIAC
2.4.2.2.4	Respiratory Water Loss		CBIAC
2.4.2.2.5	Skin Dehydration		CBIAC
2.4.2.3	Nausea		CBIAC
2.4.2.4	Pain		CSERIAC
2.4.2.5	Environmental Stressor Effects		Battelle Pacific Northwest Laboratory
2.4.2.5.1	Motion Sickness		CBIAC
2.4.2.5.2	Radiation Sickness		DNA HRP; DNA IDP
2.4.3	Mental Illness		CSERIAC
2.4.3.1	Illusion		Boff, et al. (1986)
2.4.3.2	Hallucination		CSERIAC
2.4.4	Nutrition		ARIEM
2.4.5	Exercise		ARIEM; SAM
2.4.5.1	Dynamic Flexibility		Fleishman (1975)

2.4.5.2	Dynamic Strength	Fleishman (1975)
2.4.5.3	Equilibrium	Fleishman (1975)
2.4.5.4	Explosive Strength	Fleishman (1975)
2.4.5.5	Extent Flexibility	Fleishman (1975)
2.4.5.6	Gross Body Coordination	Fleishman (1975)
2.4.5.7	Stamina	Fleishman (1975)
2.4.5.8	Static Strength	Fleishman (1975)
2.4.5.9	Trunk Strength	Fleishman (1975)
3	**Task**	Boff, et al. (1986)
3.1	***Control Device***	Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.1.1	Type	Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.1.1.1	Knob	Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.1.1.2	Lever	Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkad (1972)
3.1.1.3	Pedal	Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.1.1.4	Pushbutton	Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.1.1.5	Switch	Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.1.1.5.1	Rocker	Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.1.1.5.2	Rotary Selector	Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.1.1.5.3	Toggle	Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.1.1.6	Track Ball	Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.1.1.7	Touch Device	Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.1.1.7.1	Keyboard	Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.1.1.7.1.1	Membrane	Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.1.1.7.1.2	Teletype	Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.1.1.7.2	Light Pen	Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.1.1.7.3	Pointer	Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.1.1.7.4	Touch Panel	Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.1.1.7.5	Touch Screen	Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.1.1.8	Voice Activated	Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.1.1.9	Wheels	Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)

3.1.1.9.1	Steering Wheel	Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.1.1.9.2	Thumb Wheel	Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.1.1.9.3	Eye Tracker	Bolt (1984)
3.1.1.9.4	Command Language	Bierman, Rodman, Rubin, and Heidlage (1985)
3.1.2	Attributes	Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.1.2.1	Number Of Positions	Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.1.2.2	Size	Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.1.2.3	Type Damping	Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.1.2.4	Type Feedback	Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2	***Display Device***	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.1	Type	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.1.1	Auditory Display	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.1.1.1	Electromechanical	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.1.1.1.1	Bell	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.1.1.1.2	Buzzer	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.1.1.1.3	Horn	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.1.1.1.4	Siren	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.1.1.2	Electronic	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.1.1.2.1	Electronic Tone and Signal	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.1.1.2.2	Recorded Signal Direction	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.1.2	Visual	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.1.2.1	CRT Alphanumeric–Pictorial Display	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)

3.2.1.2.1.1	Computer Output Display	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.1.2.1.2	Infrared Sensor Display	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.1.2.1.3	Low-Light-Level TV Display	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.1.2.1.4	Television Output Display	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.1.2.2	CRT Electronic Parameter Display	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.1.2.2.1	Analog Computer Output Display	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.1.2.2.2	Bargraph Display	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.1.2.2.3	Waveform Display	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.1.2.3	CRT Spatial Relation Display	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.1.2.3.1	Radar Display	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.1.2.3.2	Sonar Display	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.1.2.4	Hard Copy Readout Display	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.1.2.4.1	Plotter	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.1.2.4.2	Printer	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.1.2.4.3	Recorder	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.1.2.5	Indicator Light (Transilluminated)	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.1.2.5.1	Lighted Pushbutton Display	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.1.2.5.2	Multiple Status	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.1.2.5.3	Single Status	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.1.2.6	Light Emitting Diode (LED)	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)

3.2.1.2.7	Liquid Crystal Diode (LCD)	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.1.2.8	Mechanical	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.1.2.9	Projection	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.1.2.10	Random–Access Digital Readout	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.1.2.10.1	Back–lighted Belt Display	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.1.2.10.2	Cold Cathode Tube	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.1.2.10.3	Edge–lighted Plate	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.1.2.10.4	Light–emitting Diode Display	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.1.2.10.5	Projection Readout	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.1.2.10.6	Segmented Matrix	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.1.2.11	Scalar Display	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.1.2.11.1	Fixed Pointer, Moving Scale	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.1.2.11.2	Moving Pointer, Fixed Scale	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.1.2.12	Sequential Access Digital Readout	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.1.2.12.1	Electromechanical Drum Counter	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.1.2.12.2	Flag Counter	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.1.2.13	Status Display	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.1.2.13.1	Large Screen Display	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.1.2.13.2	Map Display	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.1.2.13.3	Matrix Board	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)

3.2.1.2.13.4	Plot Board		Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.1.2.13.5	Projected Display		Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.2	Attributes		Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.2.1	Size	centimeters	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.2.1.1	Diameter	centimeters	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.2.1.2	Height	centimeters	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.2.1.3	Width	centimeters	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.2.2	Viewing Condition		Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.2.2.1	Collimation		Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.2.2.2	Distance of Operator	centimeters	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.2.2.3	Magnification		Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.2.2.4	Ocular Design		Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.2.2.4.1	Binocular		Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.2.2.4.2	Dichoptic		Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.2.2.4.3	Monocular Left Eye		Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.2.2.4.4	Monocular Right Eye		Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.2.2.5	Resolution		Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.2.2.2.6	Visual Angle/Field of View	degrees	Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.3	***Machine***		Bailey (1982); Boff, et al. (1986); Boff and Lincoln (1988); Van Cott and Kinkade (1972)
3.3.1	Computer		Card, Moran, and Newell (1976); Salvendy (1987)

3.3.1.1	Mainframe	Card, Moran, and Newell (1976; Salvendy (1987)
3.3.1.2	Personal	Card, Moran, and Newell (1976; Salvendy (1987)
3.3.1.3	Software Useability	Card, Moran, and Newell (1976; Salvendy (1987)
3.3.1.3.1	Aspects Affecting Adaptivity of System	Edmonds (1986)
3.3.1.3.1.1	Common User Errors	Edmonds (1986)
3.3.1.3.1.2	User Characteristics	Edmonds (1986)
3.3.1.3.1.3	User Performance	Edmonds (1986)
3.3.1.3.1.4	User Goals	Edmonds (1986)
3.3.1.3.1.5	Environment	Edmonds (1986)
3.3.1.3.2	Methods of Adaptation Onset	Edmonds (1986)
3.3.1.3.2.1	On Request	Edmonds (1986)
3.3.1.3.2.2	Prompted	Edmonds (1986)
3.3.1.3.2.3	Automatic	Edmonds (1986)
3.3.2	Vehicle	Taylor, Munson, and Taylor (1989)
3.3.2.1	Type	Taylor, Munson, and Taylor (1989)
3.3.2.1.1	Aircraft	Taylor, Munson, and Taylor (1989)
3.3.2.1.1.1	Helicopter	Taylor, Munson, and Taylor (1989)
3.3.2.1.1.2	Jet	Taylor, Munson, and Taylor (1989)
3.3.2.1.1.3	Propeller	Taylor, Munson, and Taylor (1989)
3.3.2.1.1.4	Airship	Taylor, Munson, and Taylor (1989)
3.3.2.1.1.5	Hovercraft	Taylor, Munson, and Taylor (1989)
3.3.2.1.1.6	Remotely Piloted Vehicles	Taylor, Munson, and Taylor (1989)
3.3.2.1.1.7	Parachute	Taylor, Munson, and Taylor (1989)
3.3.2.2	Attributes	Taylor, Munson, and Taylor (1989)
3.3.2.2.1	Maintenance Status	Wicks, et al. (1989)
3.3.2.1.2	Motorized Ground Vehicle	SIMNET
3.3.2.1.2.1	Car	SIMNET
3.3.2.1.2.2	Half Track	SIMNET
3.3.2.1.2.3	Jeep	SIMNET
3.3.2.1.2.4	Tank	SIMNET
3.3.2.1.2.5	Truck	SIMNET
3.3.2.1.2.6	Other Armored Vehicles	SIMNET
3.3.2.1.2.6.1	Wheeled	SIMNET
3.3.21..2.6.2	Tracked	SIMNET
3.3.2.1.3	Ship	Naval Biodynamics Lab
3.3.2.1.3.1	Aircraft Carrier	Naval Biodynamics Lab
3.3.2.1.3.2	Destroyer	Naval Biodynamics Lab
3.3.2.1.3.3	Submarine	Naval Biodynamics Lab
3.3.2.1.4	Spacecraft	CSERIAC
3.3.3	Weapon	CSERIAC
3.4	***Stimulus***	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC

3.4.1	Type	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.1.1	Auditory	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.1.2	Kinesthetic	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.1.3	Visual	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.1.3.1	Alphanumeric	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.1.3.2	Graph	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.1.3.3	System User Documentation	Brown (1984)
3.4.1.4	Tactile	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2	Attributes	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2.1	Background	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2.1.1	Complexity	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2.1.2	Contrast	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2.1.3	Number of Background Characters	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2.2	Characteristics	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2.2.1	Alphanumeric	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2.2.2	Changing/Moving Stimulus	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2.2.3	Coded Stimulus	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2.2.4	Conspicuity	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2.2.5	Raw Stimulus	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2.2.6	Static Stimulus	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2.3	Color	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2.4	Duration	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2.4.1	Continuous	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2.4.2	Intermittent	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2.4.2.1	Probability	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2.4.2.2	Rate	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2.4.3	Single	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2.5	Information Presented	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC

3.4.2.5.1	Content	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2.5.2	Qualitative	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2.5.3	Quantitative	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2.6	Location on Display	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2.6.1	Center	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2.6.2	Lower Left	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2.6.3	Lower Middle	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2.6.4	Lower Right	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2.6.5	Middle Left	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2.6.6	Middle Right	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2.6.7	Upper Left	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2.6.8	Upper Middle	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2.6.9	Upper Right	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2.6.10	Predictability of Location	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2.7	Mechanism	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2.7.1	Directly Viewed Event	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2.7.2	Display	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2.7.3	Written Material	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2.8	Number	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2.8.1	Multiple	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2.8.2	Single	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2.9	Range Of Values	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2.10	Relative Movement	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2.10.1	Observer And Target At Rest	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2.10.2	Observer And Target In Motion	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2.10.3	Observer In Motion, Target At Rest	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2.10.4	Observer At Rest, Target In Motion	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC

3.4.2.11	Relative Position Of Observer		Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2.11.1	Horizontal Range	km	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2.11.2	Offset	km	Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2.11.3	Positions		Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2.11.3.1	Air–To–Air		Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2.11.3.2	Air–To–Ground		Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2.11.3.3	At a Display		Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2.11.3.4	Ground–to–Air		Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2.11.3.5	Ground–to–Ground		Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2.12	Size/Amplitude		Boff, et al. (1986); Boff and Lincoln (1988); CSERIAC
3.4.2.13	Discriminability	d'	CTC Archives; MIL–STD 1388
3.5	***Task Element***		CSERIAC
3.5.1	Type		CSERIAC
3.5.1.1	Communication		AAMRL
3.5.1.1.1	Type		CSERIAC
3.5.1.1.1.1	Advise		CSERIAC
3.5.1.1.1.2	Answer		CSERIAC
3.5.1.1.1.3	Communicate		CSERIAC
3.5.1.1.1.3.1	Job–Related		CSERIAC
3.5.1.1.1.3.2	Public–Related		CSERIAC
3.5.1.1.1.4	Comprehend		CSERIAC
3.5.1.1.1.5	Coordinate		CSERIAC
3.5.1.1.1.6	Direct		CSERIAC
3.5.1.1.1.7	Indicate		CSERIAC
3.5.1.1.1.8	Inform		CSERIAC
3.5.1.1.1.9	Instruct		CSERIAC
3.5.1.1.1.10	Request		CSERIAC
3.5.1.1.1.11	Supervise		CSERIAC
3.5.1.1.1.12	Transmit		CSERIAC
3.5.1.1.2	Attributes		CSERIAC
3.5.1.1.2.1	Oral		CSERIAC
3.5.1.1.2.2	Written		CSERIAC
3.5.1.2	Mediation		CSERIAC
3.5.1.2.1	Type		CSERIAC
3.5.1.2.1.1	Information Processing		CSERIAC
3.5.1.2.1.1.1	Categorize		CSERIAC
3.5.1.2.1.1.2	Calculate		CSERIAC
3.5.1.2.1.1.3	Code		CSERIAC
3.5.1.2.1.1.4	Compute		CSERIAC

3.5.1.2.1.1.5	Interpolate		CSERIAC
3.5.1.2.1.1.6	Itemize		CSERIAC
3.5.1.2.1.1.7	Learn		CSERIAC
3.5.1.2.1.1.8	Tabulate		CSERIAC
3.5.1.2.1.1.9	Translate		CSERIAC
3.5.1.2.1.2	Problem Solving and Decision Making	time in seconds, number of errors	HRL
3.5.1.2.1.2.1	Analyze		CSERIAC
3.5.1.2.1.2.2	Deduce		CSERIAC
3.5.1.2.1.2.3	Induce		CSERIAC
3.5.1.2.1.2.4	Calculate		CSERIAC
3.5.1.2.1.2.5	Choose		CSERIAC
3.5.1.2.1.2.5.1	Choose from Known Alternatives		CSERIAC
3.5.1.2.1.2.5.2	Choose from Unknown Alternatives		CSERIAC
3.5.1.2.1.2.5.3	Choose from Unspeci– fied Alternatives		CSERIAC
3.5.1.2.1.2.6	Compare		CSERIAC
3.5.1.2.1.2.6.1	Order		CSERIAC
3.5.1.2.1.2.7	Compute		CSERIAC
3.5.1.2.1.2.8	Estimate		CSERIAC
3.5.1.2.1.2.9	Integrate		CSERIAC
3.5.1.2.1.2.10	Plan		CSERIAC
3.5.1.2.1.2.11	Supervise		CSERIAC
3.5.1.2.1.2.12	Predict the Occurrence of an Event		CSERIAC
3.5.1.2.1.3	Recall		CSERIAC
3.5.1.2.1.3.1	Recall Facts		CSERIAC
3.5.1.2.1.3.2	Recall Principles		CSERIAC
3.5.1.2.1.3.3	Recall Procedures		CSERIAC
3.5.1.2.1.3.4	Timeshare		CSERIAC
3.5.1.2.2	Attributes		CSERIAC
3.5.1.2.2.1	Complexity		CSERIAC
3.5.1.2.2.2	Difficulty		CSERIAC
3.5.1.3	Motor Processes		CSERIAC
3.5.1.3.1	Type		CSERIAC
3.5.1.3.1.1	Complex–Continuous		CSERIAC
3.5.1.3.1.1.1	Adjust		CSERIAC
3.5.1.3.1.1.2	Align		CSERIAC
3.5.1.3.1.1.3	Insert Object		CSERIAC
3.5.1.3.1.1.4	Regulate		CSERIAC
3.5.1.3.1.1.5	Remove Object		CSERIAC
3.5.1.3.1.1.6	Synchronize		CSERIAC
3.5.1.3.1.1.7	Track		CSERIAC
3.5.1.3.1.1.7.1	Visual Tracking Only		CSERIAC
3.5.1.3.1.1.7.2	Visual Tracking Plus Position Plotting		CSERIAC

3.5.1.3.1.1.8	Type Message on Keyboard	CSERIAC
3.5.1.3.1.1.9	Write	CSERIAC
3.5.1.3.1.2	Compound	CSERIAC
3.5.1.3.1.3	Reflex	CSERIAC
3.5.1.3.1.3.1	Intersegmental	CSERIAC
3.5.1.3.1.3.2	Segmental	CSERIAC
3.5.1.3.1.3.3	Suprasegmental	CSERIAC
3.5.1.3.1.4	Simple–Discrete	CSERIAC
3.5.1.3.1.4.1	Activate	CSERIAC
3.5.1.3.1.4.2	Close	CSERIAC
3.5.1.3.1.4.3	Connect	CSERIAC
3.5.1.3.1.4.4	Disconnect	CSERIAC
3.5.1.3.1.4.5	Join	CSERIAC
3.5.1.3.1.4.6	Move	CSERIAC
3.5.1.3.1.4.6.1	Lift Object	CSERIAC
3.5.1.3.1.4.6.2	Drop Object	CSERIAC
3.5.1.3.1.4.6.3	Swim	CSERIAC
3.5.1.3.1.4.7	Press	CSERIAC
3.5.1.3.1.4.8	Set	CSERIAC
3.5.1.3.1.4.9	Turn Single Rotary Control	CSERIAC
3.5.1.3.2	Attributes	CSERIAC
3.5.1.3.2.1	Ballistic	CSERIAC
3.5.1.3.2.2	Continuous	CSERIAC
3.5.1.3.2.3	Coordinated	CSERIAC
3.5.1.3.2.4	Fine	CSERIAC
3.5.1.3.2.5	Gross	CSERIAC
3.5.1.3.2.6	Repetitive	CSERIAC
3.5.1.3.2.7	Serial	CSERIAC
3.5.1.3.2.8	Static	CSERIAC
3.5.1.4	Perceptual Processing	Boff, et al. (1986); Boff and Lincoln (1988)
3.5.1.4.1	Searching For and Receiving Information	CSERIAC
3.5.1.4.1.1	Detect	CSERIAC
3.5.1.4.1.1.1	Detect Nonverbal Cues	CSERIAC
3.5.1.4.1.1.1.1	Detect Movement	CSERIAC
3.5.1.4.1.1.2	Detect Verbal Cues	CSERIAC
3.5.1.4.1.2	Inspect	CSERIAC
3.5.1.4.1.3	Observe	CSERIAC
3.5.1.4.1.4	Read	CSERIAC
3.5.1.4.1.5	Receive	CSERIAC
3.5.1.4.1.6	Scan	CSERIAC
3.5.1.4.1.7	Survey	CSERIAC
3.5.1.4.2	Identifying Objects, Actions, Events	CSERIAC

3.5.1.4.2.1	Discriminate	CSERIAC
3.5.1.4.2.1.1	Discriminate Auditory Cues	CSERIAC
3.5.1.4.2.1.2	Discriminate Kinetic Cues	CSERIAC
3.5.1.4.2.1.3	Discriminate Tactile Cues	CSERIAC
3.5.1.4.2.1.4	Discriminate Nonverbal Cues	CSERIAC
3.5.1.4.2.1.5	Discriminate Verbal Cues	CSERIAC
3.5.1.4.2.1.6	Discriminate Visual Cues	CSERIAC
3.5.1.4.2.2	Identify	CSERIAC
3.5.1.4.2.2.1	Identify Nonverbal Cues	CSERIAC
3.5.1.4.2.2.2	Identify Verbal Cues	CSERIAC
3.5.1.4.2.3	Recognize	CSERIAC
3.5.1.4.2.3.1	Recognize Nonverbal Cues	CSERIAC
3.5.1.4.2.3.2	Recognize Verbal Cues	CSERIAC
3.5.2	Attributes	CSERIAC
3.5.2.1	Amount Of Labor Required	CSERIAC
3.5.2.2	Complexity	CSERIAC
3.5.2.3	Degree Of Response Chaining	CSERIAC
3.5.2.4	Difficulty	CSERIAC
3.5.2.5	Knowledge Of Results	CSERIAC
3.5.2.6	Output	CSERIAC
3.5.2.7	Pacing	CSERIAC
3.5.2.8	Precision	CSERIAC
3.5.2.9	Repetitiveness	CSERIAC
3.5.2.10	Skill Demands	CSERIAC
3.5.2.11	Simultaneity Of Responses	CSERIAC
3.5.2.12	Task Autonomy	CSERIAC
3.5.2.13	Task Allocation	CSERIAC
3.5.2.14	Payoff Matrix	CSERIAC
3.5.2.15	External Work	CSERIAC
3.6	***Personal Equipment***	Human Engineering Laboratory (HEL); MIL–STD 1472D; MIL–STD 46885D
3.6.1	Night Vision Goggle	AAMRL/HE; Night Vision Laboratory (NVL)
3.6.2	Mask	CBIAC
3.7	***System***	
3.7.1	Type	Meister (1989)
3.7.1.1	Mission–Oriented Systems	Meister (1989)
3.7.1.1.1	Weapon Device	Meister (1989))

3.7.1.1.2	Military Unit	Meister (1989)
3.7.1.1.3	Information Collection/Assess–ment	Meister (1989)
3.7.1.1.4	Communication	Meister (1989)
3.7.1.1.5	Training	Meister (1989)
3.7.1.1.6	Coordination and Decision–Making	Meister (1989)
3.7.1.1.7	Management	Meister (1989)
3.7.1.1.8	Production	Meister (1989)
3.7.1.1.9	Judicial	Meister (1989)
3.7.1.1.10	Support	Meister (1989)
3.7.1.1.11	Transportation	Meister (1989)
3.7.1.2	Service–Oriented Systems	Meister (1989)
3.7.1.2.1	Product Distributions	Meister (1989)
3.7.1.2.2	Product Servicing	Meister (1989)
3.7.1.2.3	Entertainment	Meister (1989)
3.7.1.2.4	Health Provider	Meister (1989)
3.7.1.2.5	Habitation	Meister (1989)
3.7.1.2.6	Environmental	Meister (1989)
3.7.1.3	Mixed Systems	Meister (1989)
3.7.1.3.1	Communication	Meister (1989)
3.7.1.3.2	Governmental	Meister (1989)
3.7.1.3.3	Personnel Transportation	Meister (1989)
3.7.1.3.4	General Education	Meister (1989)
3.7.1.4	Functions	Meister (1989)
3.7.1.4.1	Maintain	Meister (1989)
3.7.1.4.2	Distribute	Meister (1989)
3.7.1.4.3	Combat	Meister (1989)
3.7.1.4.4	Analyze	Meister (1989)
3.7.1.4.5	Communicate	Meister (1989)
3.7.1.4.6	Fabricate	Meister (1989)
3.7.1.4.7	Train	Meister (1989)
3.7.1.4.8	Entertain	Meister (1989)
3.7.1.4.9	Service	Meister (1989)
3.7.1.4.10	Transport	Meister (1989)
3.7.1.4.11	Grow	Meister (1989)
3.7.1.4.12	Mine	Meister (1989)
3.7.1.4.13	Manage	Meister (1989)
3.7.1.4.14	Study	Meister (1989)
3.7.1.4.15	Succor	Meister (1989)
3.7.1.4.16	Control	Meister (1989)
3.7.1.4.17	Rescue	Meister (1989)
3.7.1.4.18	House	Meister (1989)
3.7.1.4.19	Dispatch	Meister (1989)
3.7.1.4.20	Compute	Meister (1989)
3.7.1.4.21	Fish	Meister (1989)

3.7.1.4.22	Process	Meister (1989)
3.7.1.4.23	Inspect	Meister (1989)
3.7.2	Structure	Meister (1989)
3.7.2.1	Size	Meister (1989)
3.7.2.2	Number of Subsystems	Meister (1989)
3.7.2.3	Number of Personnel	Meister (1989)
3.7.2.4	System Organization	Meister (1989)
3.7.2.5	Communication Channels	Meister (1989)
3.7.2.5.1	Number	Meister (1989)
3.7.2.5.2	Internal/External to System	Meister (1989)
3.7.2.6	Complexity	Meister (1989)
3.7.2.7	Method of Control	Meister (1989)
3.7.2.8	Number of Hierarchical Levels	Meister (1989)
3.7.2.9	Internal Processes	Meister (1989)
3.7.2.9.1	Repetitive	Meister (1989)
3.7.2.9.2	Nonrepetitive	Meister (1989)
3.7.2.9.3	Fixed/Proceduralized	Meister (1989)
3.7.2.9.4	Flexible/Nonproceduralized	Meister (1989)
3.7.2.9.5	Automated	Meister (1989)
3.7.2.9.6	Semi–Automated	Meister (1989)
3.7.2.9.7	Mostly Manual	Meister (1989)
3.7.2.10	Subsystem Performance Relative to Mission	Meister (1989)
3.7.2.10.1	Continuous	Meister (1989)
3.7.2.10.2	Intermittent	Meister (1989)
3.7.2.10.3	Operation Prior to Mission	Meister (1989)
3.7.2.10.4	Operation Subsequent to Mission	Meister (1989)
3.7.2.10.5	Operation Early in Mission	Meister (1989)
3.7.2.10.6	Operation Late in Mission	Meister (1989)
3.7.2.11	Subsystem Mission Role	Meister (1989)
3.7.2.11.1	Performance of Primary Mission	Meister (1989)
3.7.2.11.2	System Support	Meister (1989)
3.7.2.12	Subsystem Boundaries	Meister (1989)
3.7.2.12.1	Well–Defined	Meister (1989)
3.7.2.12.2	Poorly Defined	Meister (1989)
3.7.2.13	Subsystem Dependency	Meister (1989)
3.7.2.13.1	Completely Dependent	Meister (1989)
3.7.2.13.2	Partially Dependent	Meister (1989)
3.7.2.13.3	None (Independent)	Meister (1989)
3.7.3	Outputs	Meister (1989)
3.7.3.1	Type	Meister (1989)
3.7.3.1.1	Fabricated Products	Meister (1989)
3.7.3.1.2	Repaired Products	Meister (1989)
3.7.3.1.3	Geographic Movement	Meister (1989)
3.7.3.1.4	Communications	Meister (1989)

3.7.3.1.5	Weapons Delivery Products	Meister (1989)
3.7.3.1.6	Decisions	Meister (1989)
3.7.3.1.7	Information	Meister (1989)
3.7.3.1.8	Services	Meister (1989)
3.7.3.1.9	Training Outputs	Meister (1989)
3.7.3.2	Number	Meister (1989)
3.7.3.2.1	Single	Meister (1989)
3.7.3.2.2	Multiple	Meister (1989)
3.7.3.2.3	Fixed Number	Meister (1989)
3.7.3.2.4	Variable Number	Meister (1989)
3.7.3.3	Frequency	Meister (1989)
3.7.3.3.1	Continuous	Meister (1989)
3.7.3.3.2	Intermittent	Meister (1989)
3.7.3.4	Outputs Produced By	Meister (1989)
3.7.3.4.1	Equipment	Meister (1989)
3.7.3.4.2	Personnel	Meister (1989)
3.7.3.4.3	Both in Interaction	Meister (1989)
3.7.3.4.4	Both, But Not In Interaction	Meister (1989)
3.7.3.5	Effect	Meister (1989)
3.7.3.5.1	Change in Other Systems and/ or Environment	Meister (1989)
3.7.3.5.2	Change in Own System and/ or Subsystem	Meister (1989)
3.7.3.5.3	Increase/Decrease in Inventory of Objects	Meister (1989)
3.7.3.5.4	Increase/Decrease in Inventory of Personnel	Meister (1989)
3.7.3.5.5	Change in Nature of Personnel	Meister (1989)
3.7.3.5.6	User Satisfaction Increased/ Decreased	Meister (1989)
3.7.3.5.7	No Effect	Meister (1989)
3.7.3.5.8	Effect Unknown	Meister (1989)
3.7.4	Feedback	Meister (1989)
3.7.4.1	Type	Meister (1989)
3.7.4.1.1	Verbal	Meister (1989)
3.7.4.1.2	Displayed	Meister (1989)
3.7.4.1.3	Written	Meister (1989)
3.7.4.2	Reference	Meister (1989)
3.7.4.2.1	Individual	Meister (1989)
3.7.4.2.2	Team	Meister (1989)
3.7.4.2.3	Subsystem	Meister (1989)
3.7.4.2.4	System	Meister (1989)
3.7.4.3	Characteristics	Meister (1989)
3.7.4.3.1	Specific	Meister (1989)
3.7.4.3.2	General	Meister (1989)
3.7.4.3.3	Rewarding	Meister (1989)
3.7.4.3.4	Neutral	Meister (1989)

3.7.4.3.5	Negative	Meister (1989)
3.7.4.3.6	Immediate	Meister (1989)
3.7.4.3.7	Delayed	Meister (1989)
3.7.4.4	Frequency	Meister (1989)
3.7.4.4.1	Continuous	Meister (1989)
3.7.4.4.2	Intermittent	Meister (1989)
3.7.4.4.3	Very Intermittent	Meister (1989)
3.8	***Characteristics***	
3.8.1	Number of Output Units	Samaras (1988)
3.8.2	Duration for Which an Output Must Be Maintained	Samaras (1988)
3.8.3	Number of Elements per Output Unit	Samaras (1988)
3.8.4	Workload	Samaras (1988)
3.8.5	Difficulty of Goal Attainment	Samaras (1988)
3.8.6	Precision of Responses	Samaras (1988)
3.8.7	Response Rate	Samaras (1988)
3.8.8	Simultaneity of Responses	Samaras (1988)
3.8.9	Degree of Muscular Effort Involved	Samaras (1988)
3.8.10	Number of Procedural Steps	Samaras (1988)
3.8.11	Dependency of Procedural Steps	Samaras (1988)
3.8.12	Adherence to Procedures	Samaras (1988)
3.8.13	Procedural Complexity	Samaras (1988)
3.8.14	Variability of Stimulus Location	Samaras (1988)
3.8.15	Stimulus or Stimulus–Complex Duration	Samaras (1988)
3.8.16	Regularity of Stimulus Occurrence	Samaras (1988)
3.8.17	Operator Control of Stimulus	Samaras (1988)
3.8.18	Operator Control of Response	Samaras (1988)
3.8.19	Reaction–Time/Feedback–Lag Relationship	Samaras (1988)
3.8.20	Feedback	Samaras (1988)
3.8.21	Decision Making	Samaras (1988)
3.8.22	End–User Involvement During System Design	Good, Whiteside, Wixon, and Jones (1984)
4.	**Organization**	CSERIAC
4.1	***Culture***	CSERIAC
4.1.1	Population	CSERIAC
4.1.1.1	Group Identity	CSERIAC
4.1.1.2	Ethnic Mix	CSERIAC
4.1.1.3	Gender Mix	CSERIAC
4.1.2	Language	CSERIAC
4.1.2.1	Communication With Organization	CSERIAC

4.1.3	Psychology	CSERIAC
4.1.3.1	Cohesion	CSERIAC
4.1.3.1.1	Coordination	CSERIAC
4.1.3.1.2	Involvement	CSERIAC
4.1.3.1.3	Planning	CSERIAC
4.1.3.1.4	Communication	CSERIAC
4.1.3.1.5	Movement	CSERIAC
4.1.3.1.6	Concealment	CSERIAC
4.1.3.1.7	Shared tasks	CSERIAC
4.1.3.1.8	Stick–to–it–ness	CSERIAC
4.1.3.2	Leadership	CSERIAC
4.1.3.3	Morale/Group Climate	OASD–MRAEL (1981)
4.1.3.4	Dominance	CSERIAC
4.1.3.5	Resistance	CSERIAC
4.1.3.6	Friction	Dupuy (1987)
4.1.3.7	Diminishing Returns	Dupuy (1987)
4.1.3.8	Disruption	USAF (1970)
4.1.3.9	Uncertainty	USAF (1970)
4.1.4	Religion	USAF (1970)
4.2	***Politics***	USAF (1970)
4.2.1	Government	USAF (1970)
4.3	***Economics***	USAF (1970)
4.3.1	Science and Technology	USAF (1970)
4.3.2	Industry	USAF (1970)
4.4	***Resources***	USAF (1970)
4.4.1	Manpower	USAF (1970)
4.4.1.1	Team Training	Army Lessons Learned Management; Information System (ALLMIS); ARI CTC Archives; CATA/CALL; TPDC Joint Universal Lessons Learned System (JULLS); TPDC Reserve Component Training Data System (RCTDA)
4.4.1.2	Operating Procedures	Field Manuals; MIL–STD 46885D; Training Manuals
4.4.1.2.1	Task Allocation	Field Manuals; MIL–STD 46885D; Training Manuals
4.4.1.2.2	Doctrine	ALLMIS; Anecdotal/Historical data (HERO); ARI–CTC Archives; CATA/CALL; Field Manuals; Schools and Training Manuals; SMEs; TPDC
4.4.1.2.2.1	Procedures	ALLMIS; Anecdotal/Historical data (HERO); ARI–CTC Archives; CATA/CALL; Field Manuals; Schools and Training Manuals; SMEs; TPDC
4.4.1.2.2.2	Techniques	ALLMIS; Anecdotal/Historical data (HERO); ARI–CTC Archives; CATA/CALL; Field Manuals; Schools and Training Manuals; SMEs; TPDC

4.4.1.2.2.3	Tactics	ALLMIS; Anecdotal/Historical data (HERO); ARI–CTC Archives; CATA/CALL; Field Manuals; Schools and Training Manuals; SMEs; TPDC
4.4.1.2.3	Instruction	ALLMIS; Anecdotal/Historical data (HERO); ARI–CTC Archives; CATA/CALL; Field Manuals; Schools and Training Manuals; SMEs; TPDC
4.4.1.3	Personnel Rotation	ALLMIS; Anecdotal/Historical data (HERO); ARI–CTC Archives; CATA/CALL; Field Manuals; Schools and Training Manuals; SMEs; TPDC
4.4.1.4	Dispersion	Richardson (1960)
4.4.1.5	Defensive Posture	Clausewitz (1976)
4.4.2	Material	HEL
4.4.2.1	Shared Equipment	HEL; MIL–STD 1472D; MIL–STD 46885D; TPDC Crosswalk
4.4.2.2	Reconstitutability	Trevor Dupuy HERO model
4.5	***Group Characteristics***	Nieva, Fleischman, and Rieck (1985)
4.5.1	Group Size	Nieva, Fleischman, and Rieck (1985)
4.5.2	Group Cohesiveness	Nieva, Fleischman, and Rieck (1985)
4.5.3	Intra– and Inter–group Competition and Cooperation	Nieva, Fleischman, and Rieck (1985)
4.5.4	Communication	Nieva, Fleischman, and Rieck (1985)
4.5.5	Standard Communication Nets	Nieva, Fleischman, and Rieck (1985)
4.5.6	Homogeneity/Heterogeneity in Personality and Attitudes	Nieva, Fleischman, and Rieck (1985)
4.5.7	Homogeneity/Heterogeneity in Ability	Nieva, Fleischman, and Rieck (1985)
4.5.8	Power Distribution Within the Group	Nieva, Fleischman, and Rieck (1985)
4.5.9	Group Training	Nieva, Fleischman, and Rieck (1985)

Appendix E
HIERARCHY OF PERFORMANCE MEASURES

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1. TIME

1.1 Reaction time, i.e., time to

1.1.1 perceive event;

1.1.2 initiate movement;

1.1.3 initiate correction;

1.1.4 initiate activity following completion of prior activity;

1.1.5 detect trend of multiple related events.

1.2 Time to complete an activity already in process; i.e., time to

1.2.1 identify stimulus (discrimination time);

1.2.2 complete message, decision, control adjustment;

1.2.3 reach criterion value.

1.3 Overall (duration) time

1.3.1 time spent in activity;

1.3.2 percent time on target.

1.4 Time sharing among events

1.5 Error characteristics

1.5.1 amplitude measures;

1.5.2 frequency measures;

1.5.3 content analysis

1.5.4 change over time.

2. ACCURACY

2.1 Corrections in observations; i.e., accuracy in

2.1.1 identifying stimuli internal to system;

2.1.2 identify stimuli external to system;

2.1.3 estimating distance, direction, speed, time;

2.1.4 detection of stimulus change over time;

2.1.5 detection of trend based on multiple related events;

2.1.6 recognition: signal in noise;

2.1.7 recognition: out–of–tolerance condition.

2.2 Response–output correctness; i.e., accuracy in

2.2.1 control positioning or tool usage;

2.2.2 reading displays;

2.2.3 symbol usage, decision–making and computing;

2.2.4 response selection among alternatives;

2.2.5 serial response;

2.2.6 tracking;

2.2.7 communicating.

3. AMOUNT ACHIEVED OR ACCOMPLISHED

3.1 Response magnitude or quantity achieved

3.1.1 degree of success;

3.1.2 percentage of activities accomplished;

3.1.3 measures of achieved reliability (numerical reliability estimates).

4. FREQUENCY OF OCCURRENCE

4.1 Number of responses per unit, activity, or interval.

4.1.1 control and manipulation responses;

4.1.2 communications;

4.1.3 personnel interactions

4.1.4 diagnostic check.

4.2 Number of performance consequences per activity, unit or interval.

4.2.1 number of errors;

4.2.2 number of out–of–tolerance conditions.

4.3 Number of observing or data gathering responses

4.3.1 observations;

4.3.2 verbal or written reports;

4.3.3 requests for information;

4.3.4 rate of engagement.

5. PHYSIOLOGICAL AND BEHAVIORAL STATE

5.1 Operator/crew condition

5.1.1 physiological;

5.1.2 behavioral.

6. BEHAVIOR CATEGORIZATION BY OBSERVERS

6.1 Judgment of performance

6.1.1 rating of operator/crew performance adequacy;

6.1.2 rating of task or mission segment performance adequacy;

6.1.3 estimation or amount (degree) of behavior displayed;

6.1.4 measures of achieved maintainability;

6.1.5 equipment failure rate (mean time between failure);

6.1.6 cumulative response output;

6.1.7 proficiency test scores (written).

6.2 Magnitude achieved

6.2.1 terminal or steady–state value (e.g., temperature high point);

6.2.2 changing value or rate (e.g., degree changes per hour).

7. CONSUMPTION OR QUANTITY USED

7.1 Resources consumed per activity

7.1.1 fuel/energy conservation;

7.1.2 units consumed in activity accomplishment.

7.2 Resources consumed by time

7.2.1 rate of consumption.

7.3 Subjective reports

7.3.1 interview content analysis;

7.3.2 self–report of experience ("debriefing");

7.3.3 Peer, self or supervisor ratings;

7.3.4 analysis of operator/crew behavior characteristics;

7.3.5 determination of behavior relevance:

(1) omission of relevant behavior;

(2) occurrence of nonrelevant behavior;

7.3.6 casual description of out–of–tolerance condition.

8. WORKLOAD

8.1 Subjective

8.2 Performance

8.3 Physiological

8.3.1 Metabolic

9. PROBABILITY

9.1 P_K

9.2 Probability of completing task

9.3 Probability of error

9.4 Likelihood Ratio (λ)

9.5 P_H

10. SPACE/DISTANCE

10.1 CEP

11. ERRORS (from Boohrer, 1990, pages 244–245)

11.1 Observation of System State

11.1.1 Excessive – improper rechecking of correct readings of appropriate state variables

11.1.2 Misinterpreted – erroneous interpretation of correct readings of appropriate state
variables

11.1.3 Incorrect – incorrect readings of appropriate state variables

11.1.4 Incomplete – failure to observe sufficient number of appropriate state variables

11.1.5 Inappropriate – observations of inappropriate state variables

11.1.6 Lack – failure to observe any state variables

11.2 Choice of Hypothesis

11.2.1 Inconsistent – could not cause particular values of state variables observed

11.2.2 Unlikely – could cause values observed but much more likely causes should be considered first

11.2.3 Costly – could cause values observed but very costly (in time or money) place to start

11.2.4 Irrelevant – does not functionally relate to state variables observed

11.3 Testing of Hypothesis

11.3.1 Incomplete – stopped before reaching a conclusion

11.3.2 Acceptance – reached wrong conclusion

11.3.3 Rejection – considered and discarded correct conclusions

11.3.4 Lack – hypothesis not tested

11.4 Choice of Goal

11.4.1 Incomplete – insufficient specification of goal

11.4.2 Incorrect – choice of counterproductive goal

11.4.3 Unnecessary – choice of nonproductive goal

11.4.4 Lack – goal not chosen

11.5 Choice of Procedure

11.5.1 Incomplete – choice would not fully achieve goal

11.5.2 Incorrect – choice would achieve incorrect goal

11.5.3 Unnecessary – choice unnecessary for achieving goal

11.5.4 Lack – procedure not chosen

11.6 Execution of Procedure

11.6.1 Omitted – required step omitted

11.6.2 Repeated – unnecessary repetition of required step

11.6.3 Added – unnecessary step added

11.6.4 Sequence – required steps executed in wrong order

11.6.5 Timing – step executed too early or too late

11.6.6 Discrete – discrete control in wrong position

11.6.7 Continuous – continuous control in unacceptable range

11.6.8 Incomplete – stopped before procedure complete

11.6.9 Unrelated – unrelated inappropriate step executed

11.6.10 Incorrect grasping — wrong contact with objects (Dubrovsky, 1985)

11.6.11 Failure to check results — failure to compare the goal and the outcome (Dubrovsky, 1985)

11.6.12 Disapproaching — "incorrect departure (unintended activating of a control during departure from the just used control)" (Dubrovsky, 1985, p. 905).

Appendix F
PROGRAM COMMITTEE

PROGRAM COMMITTEE

Chairman: Stephen A. Murtaugh, Calspan Corporation

Working Group Chairs:

I. Dr. Michael Strub, Army Research Institute Field Unit, Fort Bliss

II. Dr. Valerie Gawron, Flight Research Department, Calspan Corporation

III. Eugene Visco, Model Improvement and Study Management Agency, ODUSA (OR)

IV. Sally Van Nostrand, HQ Army Laboratory Command

V. Prof. Wayne Hughes (USN Retired), Naval Postgraduate School

Floating Advisors:

Dr. L. Ron Speight, Operations Research Division, NATO SHAPE Technical Centre
Clayton J. Thomas, ACS Studies & Analyses, HQ USAF
Dr. W. Peter Cherry, Vector Research, Inc.

MORS Administrative Staff

Richard Wiles, Executive Director
Natalie Addison, Administrator/Meeting Planner
Cynthia LaFreniere, Administrative Assistant/Secretary

Appendix G
MORIMOC III: A MORS WORKSHOP

PROGRAM AGENDA

<u>TUESDAY, 27 MARCH 1990</u> 0800 - 0825

Registration

Coffee & Pastries

CNA Reception room

<u>Opening Session</u> 0830 - 0930

Call to Order and Announcements

Stephen A. Murtaugh, Director, Program Development, Calspan Corporation
Workshop Chair

<u>Host Welcome</u>

Dr. Phil Depoy, President
Center for Naval Analysis

<u>Society Welcome</u>

Mary Pace, Vice-President for Administration
Military Operations Research Society

<u>Introduction to MORIMOC III</u>

Stephen A. Murtaugh
Workshop Chair

<u>Working Group Meetings</u> 0930 - 1730

<u>Mixer</u> 1730 - ?

PROGRAM AGENDA
Page 2

WEDNESDAY, 28 MARCH 1990	
Meeting of Chairs and Floaters	0745
Working Group Meetings	0800 - 1730
Dinner	1800 - ?

THURSDAY, 29 MARCH 1990	
Meeting of Chairs and Floaters	0745
Working Group Meetings	0800 - 1000
Preparation of Overview and Results Briefings	1000 - 1400
Working Group Presentations (5 at 35 minutes)	1400 - 1730

FRIDAY, 30 MARCH 1990	
Meeting of Working Group Chairs and Floaters	0800 - 1400

To prepare material for briefings to MORS Sponsors and Proceedings

Appendix H–1
MORMOC III
WORKING GROUP MEMBERSHIP

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Masterson, Stephen
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Stuart, LTC Rod
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